SECRET
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50X1-HUM

AIRBORNE CONTROL

RADAR K-11M

TECHNICAL DESCRIPTION

(Section I - pp. 1-145)

(English Language)

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Technical Description

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I. GENERAL

1. Purpose and Use

Airborne radar equipment K-IIM is designed for searching and detecting sea surface moving or stationary targets and large ground objects irrespective of the optical visibility.

It is also meant for controlling guided missiles from the moment they are released to the moment the target is destroyed.

Radar equipment K-IIM is installed on heavy bombers, types ТУ-4КС and ТУ-16КС, intended to attack and destroy sea surface targets with guided missiles.

Before release of a guided missile from the aircraft carrier the radar equipment allows preparation of the guided missile for release to be made and performance of the equipment installed on the guided missile to be checked.

2. Composition of Radar Equipment

Radar equipment K-IIM is completed as follows:

Nos	Name of unit	Unit designation
1	2	3
1	Homing antenna	Д-1
2	Receiver-transmitter	Д-2М

1	2	3
3	Receiver	Д-3
4	Sweep unit	Д-4М
5	Indicator unit	Д-5
6	Remote indicator (PPR)	Д-6М
7	Autoselector	Д-7
8	Regulated rectifier	Д-8
9	Bank and sighting stabilization unit	Д-9
10	Tracking unit	Д-10
11	Control panel	Д-11М
12	Distribution box	Д-12М
13	Automatic control box	Д-13М
14	Amplidynes	Д-14
15	Sighting antenna	Д-15М
16	Radio-frequency sighting unit	Д-16М
17	Inverters I and II	Д-18
18	Course and pitch stabilization unit	Д-19
19	Remote control panel	Д-20
20	Course indication unit	Д-21
21	Connection box	Д-22
22	Cables	Д-23М
23	Coupling waveguide	Д-24
24	High-voltage rectifier	Д-25
25	Azimuth gyro with converter ПАГ-1Ф	Д-27
26	Recording unit	Д-26
27	Sighting station (collimator sight)	Д-29М
28	Check board K-1	ДК-17
29	Indicator ИКО-42	
30	Spare parts, tools and accessories	

Note: 1. Units Д-15М and Д-16 are made constructionally as one unit

3. Main Characteristics

No.	Name of characteristics	Designation adopted in description	Value
1	2	3	4
1	Maximum flight altitude of which station operates in navigation condition	H	10 km.
2	Distance range	d_1 d_2 d_3 d_4	10 km. 50 km. 100 km. 200 km.
3	Beam width of homing antenna: (a) in H plane (b) in E plane	 α_1 α_2	 3.4^o 2.5^o
4	Frequency of radiation during search and homing	f_1	
5	Frequency of sighting system	f_2	
6	Pulse power	W_{pulse}	90 kW
7	Mean power	W_{mean}	60 W
8	Pulse duration	τ_1 τ_2	0.5 μsec. 1 μsec.
9	Pulse repetition rate during search	n_1	
10	Pulse repetition rate during homing	n_2	
11	Sensitivity of receiving channel	η_1	94 db/mW
12	Sensitivity of sighting channel	η_2	85 db/mW
13	Crystal oscillator frequency	F_2	60 Kc/s
14	Wobbulation frequency	D	c.p.s.
15	Main intermediate frequency	f_3	30 Mc/s
16	Sighting intermediate frequency	f_4	40 Mc/s
17	Beam width of sighting antenna	α_3	$44^o \pm 2^o$

II. OPERATING PRINCIPLES OF RADAR STATION K-IIM

1. Target Search

Sea surface and ground targets are detected in the same way as in ordinary panoramic radar stations. The underlying principle of target detection is reflection of radio waves.

The radiation pattern has the form of a beam 3.4° wide in plane H, and 2.5° wide in plane E.

The azimuth position of the antenna allows the direction to the reflecting object to be found.

The speed of antenna rotation is approximately 6 r p.m.

The indicator screen has a long afterglow property and despite comparatively low antenna speed the operator can observe reflected signals on the entire surface of the screen.

Apart from circular scanning the station is capable of "painting" space within an assigned sector.

During sector scanning the brightness and contrast of the image increase, since the objects within the scanned sector are more frequently illuminated by the radiated pulses.

Depending upon the distance to the target the operator can choose one of four range scales: 10 km., 50 km., 100 km., 200 km.

The search of a target to attack is started on the 200-km. scale.

On the plan position indicator there are bright range rings (range markers) the distance between which corresponds to 10 km., 20 km., 40 km. depending upon the sweep range scale used.

When the operator is required to focus his attention on a certain section (sector) of the terrain use is made of sector scanning.

The vertical diameter of the PPI screen corresponds to the projection of the aircraft longitudinal axis.

During the antenna rotation the moment it is trained along the longitudinal axis of the aircraft may be marked on the PPI screens with a bright radial line - course line.

By using the course line, the rotary light filter with scale (calibrated in degrees from 0° to 360°) the operator can determine the course angle of the target.

Having chosen the target for attack, the operator stops the antenna in the target direction.

Then the operator changes to manual target search.

The target distance is determined approximately by range markers. By means of potentiometer RANGE (ДАЛЬНОСТЬ) located on control panel Д-11М the operator matches the range marker with the target selected. After placing the function switch on the panel in position MANUAL II (РУЧНОЕ II) the operator makes the right and left pulse pips equal on the tracking screen by using handwheels AZIMUTH (АЗИМУТ) and ELEVATION (НАКЛОН). The target being tracked is located in the sweep centre of the tracking indicator.

By placing potentiometer RANGE on the control panel in the middle fixed position the operator locks on the target and starts tracking it automatically in range.

When setting the function switch located on the control panel to position AUTOMATIC (АВТ.) the operator transfers the target to automatic tracking in angular coordinates.

2. Automatic Tracking and Selection of Target in Range

Automatic tracking and selection of a target in range is accomplished by the following main elements: variable delay circuit, comparator, integrator and selector.

The variable delay circuit produces a variable-length pulse. The leading edge of this pulse corresponds to that of the pulse radiated by the antenna, and the trailing edge may be time-shifted through variation of the D.C voltage applied to the variable delay circuit. This voltage is generated by the integrator and its magnitude may be varied either manually, by potentiometer RANGE on control panel Д-11М during manual lock-on and tracking of the target in range, or automatically by means of the comparator circuit during automatic target tracking in range. The trailing edge of the variable-length pulse triggers the sweep of the tracking indicator with 10-km. range scale and fixed delay multivibrator.

The multivibrator ensures generation of two gate pulses, range marker and a strobe pulse with a 5-km. range displacement with respect to the start of the sweep of the tracking indicator.

The gate pulses shifted by 0.7 μsec. with respect to each other are furnished one to the first valve and the other, to the second valve of the comparator. Apart from being furnished with gate pulses the both valves of the comparator are fed from the receiver output with signals of all targets picked-up by the antenna. Shifting the trailing edge of the variable-length pulse the operator matches the range marker on the tracking indicator with the wanted target echo and whereby locks on the target in range.

In this case, the signal from the selected target gets between the gate pulses. Further, if the target pulse is shifted in relation to the gate pulses, one of them is found overlapped by the target pulse more than the other and this results in positive or negative voltage at the comparator output (depending upon the displacement side of the target pulse).

These voltages are converted by the integrator into a positive control voltage. The magnitude of the control voltage is proportional to the target range, and the rate of its change - to the amount the gate pulses are overlapped by the target pulse.

When the target pulse moves towards "further" the control voltage increases and vice versa decreases when it moves towards "nearer".

This control voltage is applied to the variable delay circuit to control the length of the circuit pulse.

The trailing edge of the variable-length pulse and, consequently, of the gate pulse is shifted in time until overlapping of the gate pulses by the target pulse is equal, i.e. until the target pulse is between the gate pulses.

Thus, during movement of the target or carrier aircraft flight, the target is being continuously tracked in range.

The selector allows only those target pulses to pass through which are time-coincident with the strobe pulse. As the strobe pulse is strictly time-coincident with the gate pulses, there are only signals from the target tracked in range at the selector output.

These pulses are furnished to the system of automatic tracking of the target in angular coordinates.

Thus, due to automatic tracking and selection of the target in angular coordinates the automatic tracking in direction functions only when triggered by the signals from the targets selected by the operator by covering them with the range marker.

3. Automatic Tracking of Target in Angular Coordinates

When the station operates in automatic tracking mode the radiator of the station antenna rotates about the axis of the parabolic mirror with high angular speed.

The antenna radiator is displaced from the electrical axis of the reflector, therefore the beam of radio waves radiated by the antenna describes a cone in space whose axis is that of the antenna.

Part of space in close proximity to this axis is known as the equisignal zone.

All objects being in equisignal zone will be illuminated by radio pulses whose power is independent of the radiator position during rotation and, consequently, one or another object in the equisignal zone will reflect echo pulses whose intensity does not change during radiator rotation.

Objects outside the equisignal zone will reflect echoes whose intensity is dependent upon the position of the radiator during rotation.

Thus, the reflected signals picked up will be modulated by the rotation frequency of the antenna radiator.

The phase and modulation depth of the reflected pulses will completely characterize the location of the object with respect to the antenna axis.

The phase of pulse modulation will change with the angular position of the object with respect to the antenna.

Thus, the pulses reflected from the target and picked up by the antenna after being amplified and detected, will produce low-frequency voltage which contains information both on angular coordinates and amount of deflection from the equisignal zone.

This voltage is known as the error voltage.

Obtainment of error signal

Fig.3 shows the antenna radiation pattern. On the right of the figure is diagrammed the amount of reflected energy at various positions of the target in relation to the paraboloid axis.

The antenna is so constructed that the axis of the antenna directed electromagnetic beam is off the paraboloid axis by 1.5°.

Driven by motor 2Д-60 the radiator rotates about the optical axis of the mirror at speed 10 r.p.m. causing rotation of the antenna beam about the optical axis of the mirror so, that its maximum describes a cone in space.

Fig. 4 is a representation of the radiation pattern and the cone formed by the maximum of radiation of the antenna when it is rotated. From Fig.3 it is seen that if the target is just on the reflector axis, the receiver will pick up 50 per cent of the maximum energy irrespective of the position of the radiation pattern.

If the target is 1.5° off the paraboloid axis the reflected signal coming to the receiver will vary within 100 to 20 per cent.

Fig.5,a shows the magnitude of the picked-up reflected signal for two positions (upper and lower) of the antenna, the target being 1.5° above the paraboloid axis.

Fig.5,b shows the same for the case, when the target is on the paraboloid axis.

Fig.5 shows only two extreme positions of the radiation pattern but since the antenna is rotated continuously, the signal intensity will vary continuously between the extremities.

Fig.6 shows the change of the signal intensity per one revolution of the radiation pattern, 16 pulses being shown assumingly, though much more pulses fall on one revolution.

Such an intensity modulation of the picked-up signals is the error signal.

Fig.7,a shows a signal of the error occurring when the target is displaced in azimuth only. Fig.7,b presents an error signal formed when the target is shifted in elevation.

As it is seen from Figs 7,a and 7,b the error signal caused by the azimuth displacement of the target lags by 90° from the error signal caused by the elevation displacement.

Fig.7,c shows the error signal in azimuth and elevation.

In Fig.7 the reflector axis is shown assumingly as a point located in the centre of the circle. The axis of the radiation pattern is shown as a point describing a circle during rotation.

The target is presented in the form of a cross-hatched circle.

Deflection of the target from the direction of the paraboloid axis changes the range of variation of the echo pulse amplitude.

If the target is in the direction of the paraboloid axis (equisignal zone), the intensity of the reflected signals is constant (error signal is equal to zero). The wider the measurement range of the pulse amplitude, the greater the modulation depth and, consequently, the greater the error signal.

The echo pulses picked up are modulated by the frequency of antenna radiator rotation. The phase and modulation depth of the echo pulses fully characterize the location of the target relative to the antenna axis; the farther the object from the equisignal zone, the greater the modulation factor the echo pulses will gain.

The phase of modulation of the pulses will vary with the angular position of the object relative to the antenna.

In synchronism with the radiator is rotated the rotor of the reference voltage generator (ГОН). The generator stator has two windings shifted by 90° with each other, therefore, the sine-wave voltages produced by these windings have the frequency equal to that of the radiator rotation and are 90° out of phase with each other.

One of these voltages is the azimuth reference voltage, the other - the elevation reference voltage.

The error voltage is compared with two reference voltages in the azimuth and elevation phase detectors of unit Д-10.

As a result azimuth and elevation control voltages are produced.

These voltages after being amplified act on the actuating motors, antenna Д-1 along the azimuth and elevation axes.

4. Automatic Tracking Monitoring

The automatic target tracking is observed on a special indicator. The indicator is also used for monitoring the selection of a target for tracking in range.

The voltage supplied from the reference voltage generator and switch through a transformer switches on one or the other video amplifier in unit Д-5 and sweep intensification unit.

The change-over is done so that the screen displays the target pulses corresponding to the passage of the right and left position by the beam of the antenna during its rotation.

The target pulse pips on the screen with the target in the equisignal zone are equal in amplitude and directed in opposition.

The target being tracked is always in the centre of the sweep on the tube screen.

The targets located closer than the one being tracked will be seen in the lower portion, and the targets located farther, in the upper portion of the indicator.

5. Sighting System

The sighting system ensures reception and observation of signals from the transponder located on the guided missile.

Per each pulse radiated by the main antenna of the station the transponder produces one reply pulse at wave length τ_2.

If the transponder is moved away from station K-IIM, the reply pulse observed on the screen of the sighting indicator will depart from the start of the sweep, and the distance to the transponder can be read off from the calibration markers on the indicator screen.

Besides, the transponder is so designed that when being moved away from the equisignal line of the K-IIM antenna, the reply pulses are modulated by phase-pulse modulation.

Therefore, these pulses are seen on the screen of the sighting indicator in the form of a pulse more or less blurred in range.

The blurring width depends upon how far the transponder is moved away from the equisignal zone.

6. Beam Capture System

To facilitate catching of the guided missile by the homing antenna beam after it has been released, provision is made in the carrier aircraft for a beam capture system consisting of collimator sight K10-T (unit Д-29M), phase detector (unit Д-21) and beam capture indicator (pointer instrument ИКО-42).

Coupled to the optical system of the collimator sight is a selsyn, type A-3, which is connected electrically with azimuth selsyn A-3 of the homing antenna.

The optical system of the collimator sight is aimed at the missile after it has been released.

If the axes of the optical system and the homing antenna beam do not run in parallel, azimuth error signals will appear at the output of the sighting station selsyn.

These signals are fed to the phase-detector to be converted into a control voltage which deflects the pointer of the beam capture indicator.

Due to a program potentiometer with a timer being used in course indication unit Д-21 the deflection of instrument ИКО-42 is proportional to the distance between the carrier aircraft and equisignal zone.

On the basis of the data presented by the beam capture indicator the pilot manoeuvres the carrier aircraft so as to ensure beam capture of the missile.

7. Gyrostabilization of Antenna

The station employs bank, course and pitch stabilization of the antenna.

The bank stabilization ensures correct transmission of the phase of reference voltages to the guided missile irrespective of the carrier aircraft attitudes.

The course and pitch stabilization precludes the possibility of the automatic target tracking failure during aircraft manoeuvring or during flight in bumpy air in case of fading and other short-timed interference.

In addition, the course and pitch stabilization improves target detection during slight manoeuvres of the carrier aircraft.

Used as a transmitter of the bank, course and pitch stabilization system is a vertical gyro of autopilot АП-5.

The error signal of bank stabilization is picked off from the diagonal of a bridge formed by the bank potentiometer of the vertical gyro and test potentiometer on the antenna whose slider shaft is coupled through a reduction gear with the bank stabilization shaft.

The error signal is fed to the input of unit Д-9 and converted into a control voltage in the phase detector.

The control voltage is applied to the D.C. amplifier controlling the behavior of the relay amplifier which supplies an actuating motor, type ДК-11, turning the antenna round the bank gyrostabilization shaft.

The error signal of the antenna pitch stabilization is picked off from the diagonal of a bridge formed by a pitch potentiometer of the vertical gyro and test potentiometer whose shaft is coupled with the elevation shaft through the reduction gear and differential.

The error signal is communicated to the input of the phase detector of pitch stabilization (unit Д-19). The pitch stabilization relay amplifier of unit Д19 controls the operation of actuating motor ДК-11 coupled through a differential with the antenna elevation shaft.

In order to match the longitudinal and lateral shafts of the vertical gyro and antenna, the vertical gyro rotates in azimuth in step with the antenna.

The aircraft course data are presented by directional gyro ГПК-Д and selsyn-transformer (unit Д-27).

The receiving selsyn is mounted on the antenna and coupled with the azimuth shaft of the aircraft through the reduction gear and differential.

The error signal is passed from the transmitting selsyn rotor to the course stabilization phase detector of unit Д-19.

The relay amplifier controls the operation of actuating motor ДК-11, which turns the antenna in azimuth through the reduction gear and differential following the change in the aircraft heading.

Sighting antenna Д-15М must be trained in the same direction with the homing antenna (unit Д-1).

To control the azimuth rotation of the sighting antenna in synchronism with the rotation of the homing antenna, unit Д-15М mounts a selsyn-transformer, and unit Д-1, a transmitting selsyn.

The error signal from the selsyn transformer is supplied to the antenna control phase-detector of sighting unit Д-9.

The relay amplifier controls the operation of actuating motor ДК-11, which turns the sighting antenna until it becomes matched with the homing antenna.

8. Functional Diagram of Radar Equipment

The functions performed by separate units and stages are most diversified.

The functional diagram presented in Fig.8 gives better understanding of the operation and interaction of the units.

(1) Time Relationships

Synchronous selector unit Д-7 is used to stabilize trigger pulse repetition frequency, produce repetition frequencies radiating pulses, coordinate trigger pulses in time, as well as to synchronize the operation of certain units of the station.

The frequency is stabilized by a crystal oscillator operating at a frequency of 60 Kc/s.

The crystal oscillator pulses pass through three frequency dividers and are applied directly to or through a variable delay circuit (wobbulation phantastron Л7-4 producing pulse train wobbulation) to the blocking oscillator functioning in the 1:1 or 1:2 division mode.

The wanted division is chosen when changing the range scale by means of range-scale selector 10, 50, 100 and 200 km. located on control panel Д-11M.

This is how the required pulse train frequency n_2 is formed (during target tracking 10 km., 50 km., 100 km.) or n_1 (in 200-km. search mode).

The first in time to go is the pilot pulse of K-1 circuit (time moment t_1) (See Fig.9).

The suppressor trigger pulses in unit Д3 and sweep trigger pulses in unit Д-4M are delayed by 90 μsec. in relation to the above pulse.

The transmitter trigger pulse in unit Д-2M is delayed by 1 μsec. more relative to the trigger pulse of the suppressor and sweep.

The synchronizing pulses are communicated to the external circuits through the cathode followers.

At time moment t_1 the phantastron variable-delay circuit is started; the trailing edge of the phantastron pulse controls the generation moment of the trigger pulse of the tracking indicator (in the sweep unit), as well as the operation moment of the 34 μsec. fixed delay multivibrator.

The trailing edge of the 34 μsec. multivibrator pulse forms the range marker and triggers the generator producing 1st and 2nd gate pulses, the 2nd gate pulse being delayed by 0.7 μsec. relative to the 1st pulse with the help of a delay line.

The trigger pulses of the tracking indicator, gate pulses and range marker can move simultaneously in relation to time t_1 with mutual time delays being preserved.

Since generation of the above pulses is connected with operation of the variable-delay phantastron the change in the duration of the phantastron pulse makes it possible to move the pulses to the entire distance range and to match the range mark and gate pulses with it upon appearance of the target pulse.

The target pulse through the comparator and integrator circuits controls the pulse duration of the variable-delay phantastron keeping the gate pulses automatically in the state of balance with respect to the target pulse.

The pulse from the target being tracked and the strobe pulse are communicated to the coincidence stage.

The coincidence stage allows the pulse of the tracked target to pass through the selector channels blocking the passage through the specified channels of all the pulses from other targets.

The selected pulse is amplified and fed through the cathode followers to the external circuits (to units Д3, Д4М and Д10) where it is used for tracking the target automatically in direction and for operation of the AGC system.

(2) Receiving-Transmitting Part

Transmitting-receiving unit Д2 (modulator part) is fed from the autoselector with positive-going pulses at repetition frequency n_1 or n_2.

The incoming pulses are amplified by the trigger amplifier utilizing valve 6Н8С and passed to the control grids of submodulator valve ГИ-30.

This stage operates as a biased blocking oscillator and shapes the pulses of the required amplitude, form and duration.

From the submodulator the shaped pulses are fed to the control grids of the modulator stage consisting of two valves ГМИ-83 operating in parallel.

When fed with a pulse, the modulator valves ground the plate of the reservoir capacitor kept at high potential through their low internal resistance.

Owing to this the reservoir capacitor discharges through the magnetron and at this moment radio frequency oscillations are built up in the magnetron with frequency f_1, Mc/s.

The receiving waveguide incorporates a crystal mixer which apart from being fed with RF energy receives RF energy from the local oscillator using klystron K-19.

As a result of the action produced by two RF oscillations IF signals of 30 Mc/s are discriminated on the crystal mixer load.

These signals are fed to a three-stage IF amplifier using valves 6Ж1П.

To protect the crystal mixer from high-power pulses of RF energy propagating over the waveguide at the moment of transmission, the input of the T-R box incorporates gas discharger PP-49.

The main waveguide attaches the anti-T-R box with gas discharger PP-6, which ensures no losses of reflected signal in the magnetron channel.

Besides, the main waveguide attaches a waveguide length incorporating a crystal mixer and having elements coupled with the main waveguide and waveguide of the local oscillator.

Owing to these coupling elements the crystal mixer at the moment of transmission is supplied with two high-frequency oscillations (from the magnetron and klystron) which create IF signals across the load.

These signals are converted by the klystron AFC circuit into a control voltage being applied to the klystron repeller to make intermediate frequency constant.

The AFC circuit comprises a two-stage IF amplifier, frequency detector, two-stage video amplifier, search blocking oscillator and regulating stage.

The AFC system is of the search type.

When the intermediate frequency deviates from the wanted value the circuit produces the voltage which is used to control the oscillator frequency by varying the voltage at the klystron repeller.

The output of the IF amplifier of the transmitting-receiving unit is applied to IF amplifier unit Д3.

The output signals are amplified in the unit by the six-stage IF amplifier converted by the detector into video signals to be amplified by the video amplifier and are communicated to two cathode followers operating in series.

The output signals of the first cathode follower are furnished to the selector of unit Д7.

The selected video pulse is used in unit Д10 for automatic tracking in direction and for automatic gain control of the IF amplifiers in unit Д3 (receiver).

The output pulses of the second cathode follower are passed to sweep unit Д4M, in indicator unit Д5 and are used for observing them on the indicator screens.

(3) Sweep and Presentation System

The pips are observed on four indicators, two of them being intended for observation of the ground and target selection.

They duplicate each other's operation and are used - one by the operator, the other by the navigator.

The third indicator is intended to check the antenna direction to the selected target.

The fourth one (sighting indicator) determines the position of the guided missile in the beam and its distance to the target.

The first two indicators use radial-circular sweep, the third indicator, L-type display and the fourth one, A-type display.

The sweep voltage is formed by the circuits of the sweep unit.

There are two sweep channels in the unit, one of them is intended for beam deflection in the search and sighting indicators, the other for beam deflection in the indicator for checking the homing antenna direction which is known as the tracking indicator.

The first sweep channel is triggered by the pulses coming from unit Д7 (autoselector) for one microsecond before the transmitter starting when the sweep range scales are 50 km., 100 km., 200 km. or by the pulses with variable delay relative to the transmitter pulses when the range scale is 10 km.

For cases requiring all the range scales the variable-delay pulses are supplied for triggering the second sweep channel (tracking indicator).

The first sweep channel consists of a sweep trigger multivibrator, sweep generator and two three-stage sweep voltage amplifiers.

The required duration (range) of the saw-toothed voltage is obtained by switching range scales 10, 50, 100 and 200 on the control panel of the station.

This is accompanied by switching of resistors in the anode circuit of the sweep generator.

The first sweep channel has two outputs.

From one output the sweep voltage is applied to the deflection coils of operator's indicator Д5, from the other, to those of navigator's indicator Д6М.

The circular sweep in these indicators is obtained by rotating the deflection coils in synchronism with the rotation of the homing antenna through a selsyn drive.

The signals producing bright spots on the indicator screens are supplied from the output mixer located in the sweep unit to the video amplifiers mounted in the indicators and are further passed to the control electrodes of the cathode-ray tubes.

These signals consist of video pulses, range marks, course line marks and range calibration marks.

The latter are produced by the calibrator mounted in the sweep unit.

The first anodes of the cathode-ray tubes are fed from the sweep generator with brightening square pulses due to which the beam trace on the indicator screens is being left only during the sweep forward stroke.

The second channel comprises a driven multivibrator and a saw-toothed voltage generator.

The saw-toothed voltage is impressed on the Y-plates of the cathode-ray tube of the tracking indicator.

The X-plates of the tube are fed with video pulses.

Since the plates are fed with signals from various video amplifiers, the switching of these video amplifiers by the azimuth reference voltage results in left and right peaks being visible on the tube screen.

The right pulse corresponds to the right-hand position of the beam during the radiator rotation and the left, to the left-hand position of the beam.

The video pulses on the indicator screen are located on the left and right of the sweep trace.

If the target is exactly in the direction of the equisignal line, the amplitudes of the left and right signals are equal and their equality is used to check the target direction of the antenna.

Out of a number of video pulses arriving at the tracking indicator a signal from the selected target is marked with a range mark which is fed from unit Д7.

Being brightened by the range mark this signal is clearly visible on the screen and the range mark itself is presented on the screen as a bright spot located in the middle of the sweep trace.

The sighting indicator employs A-type display.

The sweep is formed in unit Д4М (sweep unit) and furnished to the sweep amplifier in the indicator unit (Д5) and further to the X-plates of ~~the~~ cathode-ray tube.

From the mixer in the sweep unit through the video amplifier in the indicator unit the Y-plates are furnished with the voltage of the signal which enables the distance between the missile and the target to be measured and gives estimation of the missile flight in the equisignal zone.

(4) Homing Antenna Control

The radiator system of the homing antenna may be rotated about three mutually perpendicular axes: one vertical and two horizontal.

Rotation about the vertical axis is known as rotation in azimuth, and rotation about horizontal axes is known as rotation in elevation and bank respectively.

The azimuth rotation is used to perform the following functions:

(a) Circular scanning of the ground.

(b) Sector scanning of the ground.

(c) Aiming the antenna manually to the selected target in azimuth.

(d) Automatic target tracking in azimuth.

The rotation in elevation is used for:

(a) Selection of a radius of the sweep area in the search mode.

(b) Aiming the antenna to the selected target during manual search in elevation.

(c) Automatic target tracking in elevation.

The position of the antenna in space is stabilized by the course, bank and pitch gyrostabilization system.

The gyrostabilization is effected by means of vertical gyro АП-5 and azimuth gyro Д-27 (ГПК-Д).

The antenna is rotated in azimuth by control motor Д-75 and gyrostabilization motor ДК-11.

From either motor motion is imparted through the reduction units and differential to the big azimuth gear of the antenna.

Motor Д-75 is coupled mechanically with selsyn КС-1 (transmitter), and motor ДК-11 with selsyn ПСД (flat selsyn transmitter).

During rotation of motor Д-75 angular difference occurs between the rotor of selsyn КС-1 located in the antenna (unit Д-1) and rotor of selsyn КС-2 mounted in the control panel (unit Д-11М).

The error voltage developed in the rotor of selsyn KC-2 is used for manual control of the antenna in azimuth and sector scanning.

Selsyn ПСД is connected electrically with a flat selsyn (receiver) located in the azimuth gyro (unit Д27).

The voltage developed in the rotor of this selsyn is used for course gyro stabilization.

Coupled mechanically with the azimuth rotation shaft of the antenna are selsyns СГС-1 and A-3.

Selsyn СГС-1 is designed to produce circular sweep in the plan position indicators.

Selsyn A-3 is a selsyn transmitter and operates into two selsyn receivers: receiving selsyn A-3 located in unit Д-15 and receiving selsyn A-3 located in unit Д-29M (sighting station) or into receiving selsyn A-3 in unit Д-21 (course indication unit).

The voltages developed in the rotors of these selsyns are used: one for controlling the sighting antenna in azimuth, and the other for checking the coincidence of the axes of the homing antenna and sighting station, or axis of the homing antenna with the structural axis of the aircraft.

The rotation in elevation is effected in essentially the same way as the azimuth rotation by elevation motor Д-75 and gyrostabilization motor ДК-11.

Motor Д-75 is coupled mechanically to elevation selsyn KC-1, and motor ДК-11 to the elevation potentiometer.

Selsyn KC-1 is connected electrically with elevation receiving selsyn KC-2 mounted in the control panel.

The rotor voltage of the selsyn is used for manually controlling the antenna in elevation.

The potential difference between the slider of the vertical gyro pitch potentiometer and that of the elevation potentiometer is applied to the pitch gyrostabilization circuit in unit Д-19 (pitch and course stabilization unit).

Selsyn СГСМ-1 of the homing antenna is connected electrically with selsyn СМСМ-1 of the control panel which serves as an elevation indicator.

The bank rotation is effected by motor ДК-11.

At the same time the motor rotates the slider of the bank potentiometer.

The potential difference between the slider of the bank potentiometer located in the vertical gyro and the slider of the bank potentiometer located in unit Д-1 (antenna) is supplied to unit Д-9(bank and sighting stabilization unit) for bank gyrostabilization.

The homing antenna radiator is rotated by a motor, type 2Д-60.

The radiator rotation shaft is coupled mechanically with the reference voltage generator.

The latter produces two sine-wave voltages 90° out of phase with each other.

The frequency of the reference voltages equals the frequency of the radiator rotation.

These voltages are used as reference voltages in the automatic direction tracking system.

One of these voltages is used for modulation of the repetition frequency of the radiated pulses in unit Д-7 (autoselector).

(a) Manual control

The rotor voltage of azimuth selsyn KC-2 incorporated in the control panel is furnished to the circuit in the tracking unit consisting of azimuth error signal amplifier, phase inverter, phase detector and azimuth D.C. amplifier.

The anode circuits of the azimuth D.C. amplifier contain the control windings of the azimuth amplidyne located in unit Д-14 (amplidynes) which produces voltage for azimuth motor Д-75.

Rotating handwheel AZIMUTH (АЗИМУТ) on the control panel causes unbalance of the D.C. amplifier, and motor Д-75 is supplied with the azimuth amplidyne output voltage whose polarity depends upon the direction of the handwheel rotation.

Manual control in elevation is achieved in the same way by rotating handwheel ELEVATION (НАКЛОН).

(b) Sector scanning

During sector scanning the voltages from selsyn KC-2 of the control panel are converted into a D.C. voltage varying periodically in polarity.

This voltage is being supplied to motor Д-75 and changes periodically the direction of the antenna rotation.

The sequence of conversion is as follows:

The rotor voltage of the selsyn is supplied to the circuit of unit Д-10 consisting of a sector scanning transformer, phase detector, multivibrator and sector scanning D.C. amplifier.

The anode currents of the sector scanning D.C. amplifier flow through the control windings of the azimuth amplidyne which is the one that supplies the required voltage to azimuth motor Д-75.

(c) Circular scanning

Circular scanning is effected by artificially unbalancing the D.C. amplifier from the control panel.

Setting the controls in the circular scanning mode changes the bias voltage on one half of the damping signal amplifier connected into the screen grid circuit of the D.C. amplifier, and causes unbalance of currents of the D.C. amplifier.

(d) Gyrostabilization

Gyrostabilization of the homing antenna is carried out by means of course and pitch stabilization unit (unit Д-19) and bank and sighting unit (unit Д-9).

Identical circuits of units Д-9 and Д-19 consist of error signal amplifiers, phase detectors, differentiating cells, D.C. amplifiers and relay amplifiers.

The input of each unit is supplied with 400 c.p.s. error signal, and the output produces a D.C. voltage which is then applied to the armature of the actuating motor which rotates the corresponding axle of the homing antenna to reduce the error signal.

The error signal in course is caused by angular difference between the flat selsyns (ПСД) mounted in the homing antenna (unit Д-1) and in azimuth gyro (unit Д-27).

The bank and pitch error signal is caused by the mismatch between the corresponding check bank and pitch potentiometers located in unit Д-1 and between bank and pitch potentiometers located in vertical gyro АП-5.

(e) Additional control circuits

To eliminate possible spurious oscillations of the homing antenna during manual control or automatic tracking use is made of a special feedback circuit.

Variable polarity voltages built up by azimuth and elevation motors are passed through feedback filters located in unit Д-13М (automatic control box) and fed to the control grids of the azimuth and elevation damping signal amplifiers.

The currents built up by the damping signal amplifiers in the anode circuits of the azimuth and elevation D.C. amplifiers produce at the output of the amplidynes the voltages of the agitation voltage polarity.

To retain the position of the homing antenna (matching of selsyns КС-1 of the homing antenna and КС-2 of the control panel) when changing from circular scanning and automatic tracking to manual control or sector scanning use is made of the follow-up system.

This system consists of a follow-up amplifier and a follow-up motor.

During circular scanning or automatic tracking, the error voltage from the rotor of azimuth selsyn KC-2 of unit Д-1 is applied to the follow-up amplifier unit Д-10 which produces control voltage for the follow-up motor located in unit Д-11М.

The shaft of the follow-up motor is coupled mechanically to that of the azimuth selsyn rotor through a reduction gear and differential.

(5) Follow-Up Sighting System

The reply signals from the guided missile come to the sighting antenna, then are converted by the crystal mixer into signals of intermediate frequency (f_2), amplified by the six-stage IF amplifier, converted by the second detector into video signals and after being amplified by the video amplifier are passed to the cathode follower.

From the cathode follower the video signals are communicated to the mixer of unit Д-4М and after passing the succeeding stages are displayed on the screen of the sighting indicator.

Besides, from the output of the cathode follower the video signals are furnished to the mixer in unit Д-4 and then to the video amplifier of unit Д-5 and to the Y-plates of the cathode-ray tube.

The sighting antenna is trained on the guided missile by means of a circuit which is identical with the gyrostabilization circuits incorporated in unit Д-9.

This circuit is fed with an error signal from the rotor of selsyn A-3 located in unit Д-15М (sighting antenna).

The output voltage of the above-mentioned circuit is applied to the sighting antenna azimuth motor (ДК-11) coupled mechanically to the rotation axle of the sighting antenna.

(6) Control of Radar Equipment

The main controls for tuning and checking the performance of the station are carried on the control panel. Part of controls is located on connection boxes Д-12М and Д-13М, and on the front panels of the units.

III. DESCRIPTION OF UNITS

1. Homing Antenna Д-1

The homing antenna is designed:

(a) to illuminate ground and sea surface with pulses of radio-frequency energy and pick up the reflected signals;

(b) to form a narrow symmetrical beam of the radiation pattern and the equisignal zone;

(c) to make the beam move in azimuth, elevation and bank.

The antenna assembly consists of the radio-frequency portion and electromechanical control elements.

The radio-frequency portion of the antenna assembly consists of the following main components:

1. Parabolic reflector.
2. Double-slot radiator.
3. Radiator rotating joint.
4. Elevation rotating joint.
5. Bank rotating joint.
6. Azimuth rotating joint.
7. Connecting waveguide.

The diagram of the antenna radio-frequency channel is shown in Fig.11.

Radio-frequency elements

The reflector of the homing antenna is essentially a rotary paraboloid with a focal distance of 270 mm and flare diameter of 750 mm fed by a double-slot radiator.

The reflector forms a radiation pattern, 3.4° wide in plane H and 2.5° in plane E, by half power points.

A number of metal plates mounted on the radiator feeding waveguide widens the radiation pattern in plane H and ensures that the amount of power within the bearing angles (± 5°) is not less than 0.5 per cent of P_{max}.

Radio-frequency energy is conveyed to the radiator through the feeding waveguide.

The tapered part of the waveguide turns into a resonance cavity provided with two slots through which the radio-frequency energy is fed to the reflector.

The double-slot head of the radiator is displaced relative to the reflector axis so that the axis of the antenna directional radiation does not coincide with that of the paraboloid, and departs from it through an angle of 1°30'.

By aid of a motor the radiator may rotate about the optical axis of the paraboloid at 1800 r.p.m. (30 r.p.s.) causing the antenna electromagnetic beam to rotate so that its maximum describes a cone in space.

Fig.12 shows the antenna radiation pattern and the cone formed by the maximum of radiation of the antenna during antenna rotation.

From the illustration it is seen that with a target directly on the reflector axis, the receiver will take 50 - 60 per cent of the maximum energy whatever may be the position of the radiation pattern.

If the target is off the paraboloid axis by 1°30', the intensity of the reflected signal will vary with the radiator rotating within 100 to approximately 20 per cent.

Absence of intensity-modulated echo signals (presence of signals themselves) indicates that the target is in the equisignal zone on the reflector axis.

Waveguide rotating joints

All the rotating joints are coupled with one another by means of connecting waveguides.

The waveguide run of the unit is sealed hermetically.

Rubber gaskets are provided between the flanges of the connecting waveguides to ensure air-tightness.

All the rotating joints are made air-tight by means of a tight-fitting collar of frost-resistant and wear-resistant plastic.

The radiating slots of the radiator are sealed with mica plates in metal holders.

The antenna radiation pattern in planes H and E is presented in Fig.13.

Electromechanical elements

The electric drive portion of the antenna consists of the following main components:

1. Reduction unit for rotating the antenna in azimuth (main actuating motor Д-75, auxiliary actuating motor ДК-11, azimuth sweep selsyn СГС-1, follow-up selsyn КС-1, sighting selsyn А-3, flat course transmitting selsyn ПСД).

2. Reduction unit for turning the antenna in elevation (main actuating motor Д-75, auxiliary actuating motor ДК-11, elevation selsyn КС-1, elevation indicator selsyn СГСМ-1, pitch check potentiometer).

3. Reduction unit for turning the antenna in bank (bank actuating motor ДК-11, bank check potentiometer).

4. Radiator reduction unit (turning motor 2Д-60, reference voltage generator).

5. Reduction unit of vertical gyro АП-5.

The vertical gyro rotates in azimuth in synchronism and in phase with the antenna mirror with gear radio 1:1.

The vertical gyro potentiometers are connected with the bank and pitch potentiometers of the antenna and perform the function of signal transmitters for the bank and pitch stabilization systems.

The homing antenna is rotated in azimuth by two D.C. motors M1-4, type Д-75, and M1-3, type ДК-11, which are actuating motors of the tracking (control) channels and course stabilization follow-up systems respectively.

Tilting the antenna up and down in elevation is also performed by D.C. motor M1-11, type Д-75, and M1-10, type ДК-11 (See Fig.16), which are actuating motors of the follow-up systems of the tracking (control) channels and pitch stabilization respectively.

Bank turning of the homing antenna (with respect to the elevation shaft journals) is effected by D.C. motor M1-7, type ДК-11, which is the actuating motor of the bank stabilization follow-up system.

The field windings of all the actuating motors are fed from the 27-V D.C. aircraft network.

Control voltages are applied from amplidyne unit Д-14 to the armatures of actuating motors M1-4 through the azimuth channel and M1-11 through the elevation channel.

Control voltages to the armatures of actuating motors M1-7, and M1-10, and M1-3 are supplied from the relay amplifiers of stabilization units Д-9 and Д-19 (See Figs 14, 15, 16, 17) through bank, elevation and azimuth channels (course stabilization) respectively.

The azimuth channel follow-up system controlling the antenna rotation in azimuth consists of azimuth selsyn M1-6, type KC-1, coupled through a reduction unit with the antenna, and a selsyn-transformer, type KC-2, in the control panel. The stator windings of azimuth selsyn M1-6 are connected to the respective windings of the selsyn-transformer in the control panel.

The rotor winding of the azimuth selsyn is supplied with 115 V , 400 c.p.s. from the automatic control box.

By rotating handwheel AZIMUTH (АЗИМУТ) on the control panel the operator turns the rotor of the azimuth selsyn-transformer, type KC-2, thereby introducing an error signal in the azimuth channel of tracking unit Д-10.

The error signal is being converted and amplified by the D.C. amplifier (unit Д-10) whose load is the control winding of the amplifying dynamotor (unit Д-14).

The amplidyne output voltage is being applied to the armature of the azimuth actuating motor M1-4, which turns the antenna towards decrease of the angular difference between the rotors of the selsyn pair.

The elevation channel follow-up system controlling the antenna motion in elevation operates in essentially the same manner.

In this case, the stator windings of elevation selsyn M1-12 are connected to the respective windings of the selsyn-transformer in the control panel.

The rotor winding of selsyn M1-12 is fed with 115 V, 400 c.p.s. from the automatic control box.

Synchronous rotation of the circular sweep in indicator unit Д-5 and plan position indicator Д-6 with the homing antenna is ensured by a follow-up system consisting of antenna-mounted transmitting selsyn M1-1, type СГС-1, and two receiving selsyns, type CMC-1, located in units Д-5 and Д-6M respectively.

The stator windings of the azimuth sweep selsyn (M1-1) are connected to the corresponding receiving selsyn in units Д-6M and Д-5.

The rotor windings of these selsyns are fed with 115 V, 400 c.p.s.

The above selsyns turn in synchronism.

For synchronous and inphase rotation of the sighting and homing antennas in azimuth, as well as for the receiver course indication, use is made of a sighting follow-up system consisting of sighting selsyn M1-2, type A-3, whose stator windings are connected to the corresponding windings of the selsyn-transformer, type A-3, located in course indication unit Д-15 and the corresponding windings of selsyn-transformer, type A-3, in course indication unit Д-21 (in COMBAT COURSE mode) or in sighting station Д-29M (in BEAM CAPTURE mode).

The rotor winding of selsyn M1-2 is fed with 40 V, 400 c.p.s. from the transformer in unit Д-13M.

For remote transmission of the elevation angle of the homing antenna to the pointer instrument in the control panel, a follow-up system is used consisting of transmitting selsyn M1-9, type СГСМ-1 and a receiving selsyn СМСМ-1 in unit Д-11. The stator windings of elevation selsyn indicator (M1-9) are connected to the corresponding windings of receiving selsyn СМСМ-1 whose rotor, as well as the rotor of selsyn M1-9, is fed with 115 V, 400 c.p.s.

Both selsyns turn in synchronism.

The antenna radiator and reference voltage generator M1-13 are driven round by a D.C. motor, type 2Д60 (M1-8).

The reference voltage generator produces two sinusoidal voltages shifted in phase by 90°.

These voltages are supplied as reference voltages to unit Д-10 to shape the antenna control signals during automatic tracking (See Fig.22).

Bank and pitch potentiometers R1-3 and R1-6 together with the transmitting potentiometers of the vertical gyro constitute bridges (or measuring transmitters) of the bank and pitch stabilization follow-up systems.

The measuring-transmitting bridge of the bank stabilization system is fed with 40 V, 400 c.p.s. from transformer Tp1-1 mounted on the homing antenna.

The slider of the bank-transmitting potentiometer located in vertical gyro АП-5 is earthed, and the voltage from the slider of bank potentiometer R1-3 is being applied to bank gyrostabilization unit Д-9.

Here this voltage is converted into D.C. control voltage which forces motor M1-7 to rotate in bank (the latter is coupled through a reduction gear with potentiometer R1-3) until the potential difference across the potentiometer sliders is zero.

Bank check potentiometer R1-3 mounts limit switches B1-5 and B1-6 which open the circuit of actuating motor M1-7 on the boundaries of the bank working area.

The pitch stabilization follow-up system operates in the same manner (See Fig.21).

The bridge circuit arrangement of pitch potentiometers R1-6 and R1-2 of the vertical gyro is supplied with 40 V, 400 c.p.s. from the transformer in the control panel.

Signal from the slider of potentiometer R1-2 (vertical gyro) is passed to the pitch gyrostabilization unit.

The output voltage of unit Д-19 is fed to the armature of elevation actuating motor M1-10 and rotates the antenna and the slider of pitch check potentiometer R1-6 until the pitch voltage is zero.

The antenna tilt in elevation equals 7° up and 42° down.

To limit the antenna tilting within the specified range there are two limit switches B1-3 and B1-4.

Upon operation, these switches energize relays P13-3 and P13-4 in the control panel by means of which the control windings of the elevation amplidyne are shunted by selenium rectifiers (located in the control panel).

This results in closing the amplidyne field windings and, consequently, in the elevation actuating motor (M-11) coming to a standstill.

Relays P13-3 and P13-4 break the armature circuit of elevation stabilization actuating motor M1-10 at the edge of the elevation working area.

Course stabilization follow-up system

The homing antenna is course-stabilized by means of flat transmitting selsyn M1-5 , type ПСД, coupled with the gyro compass selsyn.

The rotor of selsyn M1-5 is supplied with 40 V, 400 c.p.s. from unit Д-13; the stator windings of this selsyn are connected to the corresponding stator windings of the selsyn-transformer, type ПСД in the gyro compass.

The voltage from the selsyn-transformer rotor proportional to the angular difference between the rotors of these selsyns is fed to the input of unit Д-10 (course stabilization channel), where it is amplified and converted into D.C. voltage being supplied to actuating motor M1-3, type ДК-11 (Fig.17).

Motor M1-3 rotates the homing antenna through a reduction gear toward reduction of the course error.

Course indicator B1-1 operates to send a pulse to unit Д-5 when the antenna azimuth coincides with the lubber line of the aircraft.

Contact B1-2, through which the relay is energized to phase the circular scan selsyns of units Д-5 and Д-6, is closed by a cam whose arc is 46° (± 23° with reference to the azimuth axis of the reflector).

Elevation limiting of homing antenna Д-1

The homing antenna may tilt up and down in elevation within angle 8° up and 42° down.

Special elevation stowing switches prevent further motion of the antenna and appearance of substantial efforts during stops.

The connection diagram of the elevation stowing switches is shown in Fig.18.

Selenium rectifiers Д13-1 and Д13-2 incorporated in the automatic control box (unit Д-13M) pass currents only in one direction.

With open contacts of relays P13-4 and P13-3, the selenium rectifiers are disconnected and the antenna may be tilted up and down (depending upon the current intensity in the amplidyne control windings).

Suppose the current of valve Л10-11 prevails over that of valve Л10-12.

The antenna in this case moves upwards.

When the antenna reaches the extreme upper position the upper limit switch closes to feed + 27 V to relay P13-3.

The relay operates, which results in the amplidyne field winding being shunted by selenium rectifier Д13-1, magnetic field disappearing and antenna stopping.

When rotating the elevation handwheel on the control panel in the opposite direction, the anode currents of valves Л10-11 and Л10-12 of IF amplifier in unit Д-10 are so changed that the current in the amplidyne control windings changes its sign and the current of valve Л10-12 will prevail.

As selenium rectifier Д13-1 passes current only in one direction, it fails to shunt the field winding of the amplidyne; the antenna will start tilting down; as a result, relay P13-3 will be deenergized and break the field winding circuit shunted by selenium rectifier Д13-1.

With the antenna in the extreme lower position relay P13-4 operates to connect selenium rectifier Д13-2 which will function as mentioned above.

During simultaneous closure of the upper and lower limit switches, relays P13-3 and P13-4 break the ± 27-V circuit of the elevation relay amplifier incorporated in unit Д-19.

Remote transmission of antenna azimuth angle

The remote angle transmission system for synchronizing the azimuth rotation of the homing antenna and sweep on plan position indicators Д-5 and Д-6M comprises a transmitting selsyn, type СГС-1, located in the ~~antenna~~ azimuth reduction unit and two receiving selsyns, type CMC-1, installed in units Д-5 and Д-6M respectively.

The receiving selsyn turns the deflection coil of the indicator in stop with the azimuth rotation of the antenna.

The rotating antenna is coupled with the rotor of selsyn СГС-1 through a step-up gear ratio of 1:10, and the rotor of selsyn СМС-1 is coupled to the deflection coil of the indicator through a step-down gear ratio of 10:1.

Thus, the antenna will rotate in step with the deflection coil, and the angle the coil lags behind the antenna is 10 times as small as the angle the receiving selsyn lags behind the transmitting selsyn.

To eliminate the angular difference (which may occur with the equipment deenergized due to jolting or for a variety of other reasons) phasing cam switches are mounted on the antenna and in the indicator.

The action of cam switches is illustrated in Fig.19.

The contact units of the indicator cam switches are so assembled that, with the deflection coils positioned in a right way with respect to the antenna, the phases of selsyns СГС-1 and СМС-1 remain connected through the contact units or contacts of phasing relay P12-1 housed in the connection box of unit Д12М.

Before operation of the cam switches located on the antenna and in indicators Д-5 and Д-6М the phases of both selsyns stators are connected through the contact unit of the indicator cam switch.

When the antenna occupies the position within 157° and 203° (180° ± 23°) the phasing cam of the antenna - protrusion of the main gear rim - makes the contact unit of the antenna cam close and relay P12-1 is earthed.

The relay contacts operate to connect the phases of the stators of selsyns СГС-1 and СМС-1.

The indicator phasing cam - a protrusion on the deflection coil body - breaks its own contact unit while passing position 180° ± 18° during the coil rotation.

But the stator phases of the selsyns remain connected, since relay P12-1 contacts continue connecting the stator phases.

The operating angle of the antenna cam equals 46°, while that of indicator cam equals 36°.

If the antenna and deflection coils are phased correctly, the circuits of the selsyns will not be open during the antenna rotation since closing of the antenna-mounted switch overlaps opening in the indicator by ± 5°.

In case of dephasing the circuits will be broken and the deflection coil rotation will be retarded until the coils are in the position corresponding to that of the antenna.

2. Transmitter-Receiver Д-2М

The transmitter-receiver consists of:

1. Submodulator designed to shape the pulses triggering the modulator.
2. Modulator designed to shape powerful pulses modulating the magnetron oscillator.
3. Magnetron oscillator designed to generate powerful radio-frequency pulses.
4. Waveguide system with T-R switch, mixer and klystron oscillator.

The system is designed to receive and convert the target echoes into intermediate-frequency pulses.

5. IF preamplifier.
6. Klystron automatic frequency control circuit designed to keep intermediate frequency constant.
7. Power pack consisting of filament transformers, high-voltage rectifier feeding the modulator valve anodes, the rectifier feeding the anodes of the submodulator valves and screen grids of the modulator valves, bias rectifier for the modulator and submodulator control grids.

Schematic diagram of transmitter-receiver

Fig. 20 shows the schematic diagram of the transmitter-receiver.

The transmitter-receiver is started by positive pulses of 10-V amplitude from the autoselector lock unit.

The repetition frequency during search operation is n_1 c.p.s. during tracking is n_2 c.p.s. wobbulated at frequency 10 c.p.s.

The trigger pulse is passed through autotransformer Tp2-1 to the grid of the trigger amplifier connected as a blocking oscillator with cathode follower using 6H8C (Л2-1).

The pulse amplified to 160 V is communicated from the cathode follower to the control grids of valve ГИ-30 (Л2-2) through duration switching relay P2-1.

The submodulator uses dual beam tetrode ГИ-30 in a biased blocking oscillator circuit.

During the pulse intervals the blocking oscillator is biased negatively with $- 120 \pm 10$ V.

The bias voltage is impressed on the control grids of valve Л2-2 through grid leak R2-12 and grid suppressors R2-10 and R2-11.

The bias voltage is taken off from resistor R2-31, bias rectifier divider.

The trigger pulses drive the blocking oscillator valve Л2-2 into conduction.

The blocking oscillator produces short pulses whose length is determined by the characteristics of the valve grid circuit.

The repetition frequency of the blocking oscillator pulses corresponds to that of the pulses arriving at its grid. The valve anodes are coupled through resistors R2-8 and R2-9 to the anode winding of pulse transformer Tp2-3.

Resistors R2-4, R2-76, R2-6 and R2-5 connected in parallel with the input (grid) and output windings of the pulse transformer, serve to quench parasitic oscillations occuring on the pulse trailing edge due to parasitic parameters of the pulse transformer.

From the divider composed of R2-5 and R2-6 is taken a voltage for monitoring the submodulator pulse on the oscillograph when aligning the transmitter-receiver. The additional fifth winding produces a trigger pulse of at least 100-V amplitude.

The transmitter-receiver unit provides for operation with two pulse durations.

The durations are changed over by means of relay P2-1.

When the blocking oscillator operates with a circuit composed of L2-2 and C2-5, the pulse duration equals 0.5 ± 0.05 µsec.

When the blocking oscillator operates with a circuit composed of L2-1 and C2-6, the pulse duration equals 1 ± 0.1 µsec.

The duration switching relay is controlled from unit Д11М.

The shaped pulse is fed from the output winding of transformer Tp2-3 to the control grids of the modulator valves. The amplitude of the submodulator pulse is 1000 ± 100 V.

The transmitter modulator uses valves Л2-3, Л2-4, pulse tetrodes ГМИ-83, parallel-connected in a circuit with partial discharge of the storage capacitor.

During the pulse intervals the modulator valves are cut off on the control grids by negative bias voltage of -900 ± 50 V.

This voltage is applied to the control grids of the modulator valves by the bias rectifier from the anode of valve Л2-6 through the winding of pulse transformer Tp2-3 and resistors R2-13, R2-18.

The screen grids of the modulator valves are fed with a positive voltage of 1200 ± 50 V.

This voltage is applied to the screen grids of valves Л2-3, Л2-4 through limiting resistors R2-14, R2-15, and R2-16 from the rectifier feeding the anodes of submodulator Л2-5.

The screen grids are blocked by capacitor C2-10; in parallel with the capacitor is placed discharger PИ2-1 protecting the valve grids from maximum voltages occurring in case of intervalve breakdowns.

The modulator valves are triggered by positive pulses of 1000 ± 100 V amplitude being fed to the control grids of the modulator valves from the output winding of pulse transformer Tp2-3.

In this case, the control grids are found to be kept at a positive potential of the order of 100 to 250 V.

The valves are sharply made conductive, their internal resistance drops to some 100 ohms and the reservoir capacitor discharges partially through the valves to the magnetrons. As a result, the magnetron cathode appears to be at high negative potential.

Reservoir capacitor C2-13 has rather a large capacitance valve (0.05 microfarad), therefore during the pulse time there is no noticeable voltage drop across it, and the top of the pulses coming to the magnetron remains almost flat. Upon cessation of the positive pulse on the grids of valves Л2-3 and Л2-4 the valves are driven to cut-off, reservoir capacitor C2-13 is charged by the high-voltage rectifier (valves Л2-7 and Л2-8) through R2-17, R2-19, R2-20 almost as high as the voltage of the power source (14.5 kV). Resistor R2-20 and capacitor C2-14 constitute a measuring circuit meant for measuring the magnetron current D.C. component by a meter located on the control panel.

The magnetron is used as a high radio-frequency oscillator in the transmitter unit.

The radio-frequency energy of the magnetron is passed through the waveguide run to the antenna. The antenna is changed over to the reception or transmission channel by means of the antenna switch formed by anti-transmit-receive tube (PP6; Л2-11) and transmit-receive tube (PP-49, Л2-12) connected to the narrow side of the waveguide.

Used as a local oscillator in the unit is a klystron oscillator (Л2-10) producing continuous radio-frequency oscillations with a frequency 30 Mc/s higher than the magnetron frequency.

During reception the target echoes are communicated through the antenna to the main waveguide onto crystal mixer Д2-1. This mixer is also fed with the local oscillator output.

From the crystal mixer the IF pulses are supplied to the input of the IF preamplifier.

The IF preamplifier is a 3-stage amplifier using valves 6Ж1П (Л2-13, Л2-14, Л2-15).

When powerful magnetron pulses are transmitted into the antenna, part of the magnetron energy breaks through the attenuator with 70-db attenuation and is supplied to crystal mixer Д2-2 of the AFC channel. The same crystal mixer is supplied with radio-frequency energy from the klystron (Л2-10).

The crystal mixer output converted in the AFC mixer cell is fed in the form of IF pulses to the two-stage IF amplifier using valves 6Ж1П (Л2-16 and Л2-17), amplified by it and is coupled to discriminator, 6x6 (Л2-18). The detected pulses (video pulses) are furnished from the discriminator load to the double-stage video amplifier. From the video amplifier positive-going pulses are passed to the grid detector (half-of valve Л2-20-6Н9С).

The negative voltage regulating the klystron frequency variations is picked off the anode load of the grid detector and is coupled to the klystron repeller.

The potentiometer for manual control of the klystron repeller voltage is carried on the control panel.

The power pack of the transmitter-receiver consists of valve filament transformers and three rectifiers.

The rectifier supplying the submodulator anodes and modulator screen grids utilizes valve В1-0.02/20 (Л2-5).

The bias rectifier utilizes valve В1-0.02/20 (Л2-6).

The high-voltage rectifier utilizes valves В1-0.02/20 (Л2-7, Л2-8).

The filaments of valves Л2-1, Л2-2, Л2-3, Л2-4, Л2-5 and Л2-6 are supplied from transformer Тр2-6.

Valves Л2-7 and Л2-8 are supplied from filament transformer Тр2-7.

Magnetron oscillator Л2-9 is supplied from transformer Тр2-4.

The valve filaments of the receiving portion of the unit (valves Л2-10, Л2-13, Л2-14, Л2-15, Л2-16, Л2-17, Л2-18, Л2-19, Л-20) are supplied from filament transformer Тр2-9.

The bias and submodulator supply rectifiers (Л2-5, Л2-6) use a half-wave circuit and operate from common transformer Тр2-5.

The bias rectifier is loaded by capacitor C2-22 and a voltage divider composed of series-connected resistors R2-29, R2-81, R2-30, R2-31, R2-32. The load of the submodulator anode supply rectifier and the screen grids of the modulator are capacitor C2-19 and a voltage divider composed of resistors R2-22, R2-23, R2-24, R2-25, R2-26, R2-27.

The submodulator and modulator bias rectifier produces a voltage of - 900 ± 50 V. The voltage produced by the rectifier supplying the submodulator anodes and the screen grids of valves Л2-3, Л2-4 equals 1400 ± 50 V.

The high-voltage rectifier supplying the anodes of the modulator valves employs valves Л2-7, Л2-8 in a voltage doubler circuit.

The rectifier load is the capacitive filter formed by capacitors C2-24, C2-25, the anode circuit of the modulator valves and reservoir capacitor C2-13.

The rectified voltage at the rectifier output can be regulated by changing over the taps of transformer Тр2-8. Stepless control can be effected in box Д12M by means of a variable resistor connected in series with the primary winding of transformer Тр2-8.

Cooling is provided by fans M2-2 (Д-7) and M2-1 (Д-7) installed in the unit.

The motors are supplied from 27-V ship's mains.

When high voltage is switched on the magnetron filament voltage is automatically reduced from 6.3 V to zero.

To ensure safe attendance of the unit, the latter incorporates electrical (BK2-1) and mechanical (BK2-2) interlocks.

To protect the receiver against pulse interference via the supply circuits the modulator is provided with a number of decoupling filters.

Pressure inside the unit is checked by rheostat pressure transmitter ДД2-1 measuring the air pressure within 0.8 to 1.5 atm.

When the pressure inside the unit drops below the rated value (0.8 atm.) the pressure transmitter automatically opens the primary supply circuit of the high-voltage rectifier. Air into the unit and waveguide system is pumped with the help of a hose and a valve connected to the air main of the aircraft.

Transmitter-receiver characteristics

The frequency generated by the magnetron is f_1 Mc/s.

The average power generated by the magnetron is at least 57 W.

Pulse duration:

(a) 0.5 ± 0.05 microsec;

(b) 1.0 ± 0.1 microsec.

The pulses repetition frequency:

(a) n_2 c.p.s., wobbulated;

(b) n_1 c.p.s.

The intermediate frequency of the IF preamplifier is 30 ± 0.3 Mc/s.

The amplification factor of the IF preamplifier (K) is at least 10.

The passband of the IF preamplifier (at 0.7 voltage level) is at least 6 Mc/s.

The sensitivity of the receiver channel is at least 94 db.

The amplitude of the starting pulse is at least 100 V.

The AFC passband of the system amplifier (at 0.7 voltage level) must be at least $\pm$ 2.5 Mc/s when readings are taken with respect to 30 Mc/s.

The voltage of the klystron frequency control is 160 ± 30 V.

The unit operates on:

(a) A.C. voltage of 115 V $\pm$ 3 per cent, 400^{+40}_{-20} c.p.s.

(b) D.C. voltage of + 27 ± 2 V.

(c) D.C. regulated voltage of 300 V ± 1 V.

(d) D.C. voltage of + 140 V ± 5 per cent.

(e) D.C. regulated voltage of -225 V ± 5 per cent.

The unit consumption:

(a) Not more than 6 A in 115 V, 400 c.p.s. circuit.

(b) Not more than 3 A in 27 V circuit.

(c) Not more than 35 mA in +300 V stabilized voltage circuit.

(d) Not more than 4 mA in -255 V circuit.

Trigger stage

This is designed for amplifying the trigger pulse.

The trigger pulse is shown in Fig.21.

The trigger stage employs dual triode 6H8C. The input of the first valve includes pulse autotransformer Tp2-1 whose purpose is to amplify the trigger pulse.

The left portion of the valve functions as a blocking oscillator, the right portion, as a cathode follower.

The constants of the trigger stage are summarized in Table 1.

Table 1

U_{heater}, V	I_{heater}, A	U_{anode_1}, V	U_{anode_2}, V	E_{g1}, V	E_{g2}, V	U_{out}, V
6.3±0.2		400±50	400±50	-33±5	0	160

Submodulator

The submodulator employs valve ГИ-30 (Л2-2) in a separately excited blocking oscillator circuit. The submodulator circuit is shown in Fig.22. The blocking oscillator constants are given in Table 2.

Table 2

U_{heater}, V	I_{heater}, A	E_{g1}, V	E_{g2}, V	U_{anode}, V
6.3±0.2	2.5	-120±10	600	1400±50

The blocking oscillator is triggered by positive pulses of 160-V amplitude being passed from the trigger stage.

The trigger pulse will open the valve right after the line has been discharged. The line discharge takes place rather slowly and is entirely determined by grid leaks R2-12, R2-32. The amplitude of the pulses at the submodulator output U_{out} = 1000 V ± 100 V.

Modulator

Fig.23 shows the modulator circuit. The modulator employs two pulse tetrodes, type ГМИ-83, operating in parallel. The modulator operation is based on partial discharge of a reservoir capacitor to the magnetron through the modulator valves.

The constants of the modulator valves are tabulated below.

Table 3

U_{heater}, V	I_{heater}, A	U_{anode}, kV	I_{anode}, mA	E_{g2}, V	E_{g1}, V	U_{g1}, V
27	2.15	at least 13	12	1200±50	-900±50	1000±100

In intervals between the pulses the control grids of the modulator valves are supplied with large negative voltage E_{g1} = -900 V from the bias rectifier. The pulses of 1000 ± 100 V amplitude produced by the blocking oscillator are fed to the control grids of the modulator valves to the output winding of the blocking transformer. In this case, the valve control grids are found kept at high positive potential of + 100 to 250 V.

Voltage $E_{g2} = 1200 \pm 50$ V is applied to the screen grids of the valves from the submodulator supply rectifier through resistor R2-16, R2-15, R2-14. Resistors R2-13, R2-18 contained in the control grid circuits of the modulator valves are intended to cancel spurious oscillations in the modulator.

Reservoir capacitor C2-13 of the modulator has a 0.05-microfarad value and is rated for an operating voltage 16,000 V. During the pulse intervals it is being charged by the high-voltage rectifier through charging resistors R2-17 and R2-19. The capacitance value of the reservoir capacitor, 0.05 microfarad, ensures that the voltage pulse tilt does not exceed 5 per cent of the amplitude value.

Rectifiers

(a) Bias rectifier

The bias rectifier serves to supply negative bias voltage to the control grids of valves ГММ-83, ГИ-30 and 6H8C. It employs a kenotron, type B1-0.02/20.

The bias rectifier is loaded by filter capacitor C2-22 and resistors R2-29, R2-81, R2-30, R2-31, R2-32 connected in parallel with it. The rectified voltage equals -900 ± 100 V.

(b) Submodulator supply rectifier

The submodulator rectifier feeds positive voltage to the anode of valve ГИ-30 ($+1400 \pm 100$ V) and to the screen grids of valves ГММ-83 and ГИ-30.

Fig. 24 shows the schematic diagram of the submodulator supply rectifier and bias rectifier. Both rectifiers employ one transformer Tp2-5.

The submodulator supply rectifier uses kenotron B1-0.02/20.

(c) High-voltage rectifier supplying anodes of valves ГМИ-83

The high-voltage rectifier uses kenotrons, type B1-0.02/20, in a voltage-doubling circuit.

Fig. 25 shows the rectifier circuit. The rectifier employs two transformer Tp2-7 and Tp2-8.

Tp2-7 is a filament transformer designed to feed the filaments of the rectifier valves.

Tp2-8 is an anode transformer designed to feed the anodes of the high-voltage rectifier valves. The primary winding of transformer Tp2-8 is provided with three taps whose switching enables control of the magnitude of the high-voltage; the winding is fed with 115 V, 400 c.p.s.

Waveguide system with transmit-receive switch (radio-frequency head)

The waveguide system of the transmitter-receiver unit consists of the main waveguide connecting the magnetron oscillator with the antenna waveguide system, and a T-R switch with klystron and mixer chambers.

Radio-frequency head Д-2M meets the following requirements:

1. Minimum losses in the transmitter pulse channel are 0.2 db.
2. Minimum losses in the receiving signal channel are 2 db.
3. Possibility of frequency retuning over the frequency range $f_1 \pm 30$ Mc/s is 0.5 per cent.

The T-R switch employs an ordinary branch circuit.

Description of schematic diagram of radio-frequency head

The schematic diagram is shown in Fig.26.

Simultaneously with the picked-up signal the radio-frequency energy radiated by klystron 3 is applied to the detector through adjustable slot 1. Detector Д2-2 of the AFC channel is fed with radio-frequency energy from klystron 3 through adjustable slot 2.

Adjustable screws 1 and 2 make it possible to set the required values of the crystal currents.

Inserted in the klystron cell, across the waveguide, is absorbing plate 4 made of graphite-coated pertinax. The plate when set in a right way with reference to the short-circuited walls (5 mm) is the matched load (SWR - 1.3).

Signal detector Д2-1 is thus made to act as a converter producing IF signals which are then furnished to the input of the IF preamplifier.

The radio-frequency head and the IF preamplifier are directly coupled to each other. When the magnetron generates a strong pulse an extremely weakened magnetron signal (60-70 db attenuation) is passed to AFC crystal detector Д2-2 through round hole 5 in the main waveguide and cylindrical waveguide 6 which is, in effect, a cut-off attenuator.

From the output of the AFC crystal detector the IF signal is communicated to the input of the IF preamplifier of the AFC channel and is thus used for the control of the AFC circuit.

A sufficiently large iterative attenuation between the signal detector and AFC detector considerably improves the frequency spectrum of the pulse controlling the AFC circuit, which enhances operational reliability of the AFC system.

Capacitors C1 and C2 (6 to 8 picofarads) are constructional parameters of the crystal holders.

The keep-alive electrode of the TR cell is fed with negative voltage through anti-relaxation resistor R2-37.

The radio-frequency head has the following controls: adjusting screw of TR cell resonance frequency РЗП (8) and crystal current adjusting screws 1 and 2, adjusting screw of ATR cell resonance frequency РБП (7).

IF preamplifier

The schematic diagram of the IF preamplifier is shown in Fig.27.

The purpose of the IF preamplifier is to amplify the IF signal provided the best signal-to-noise ratio is preserved.

The IF preamplifier consists of three stages: the first two stages are a combination of an earthed-cathode triode and grid-earthed triode; the third stage is a normal pentode amplifier operating into a 90-ohm radio-frequency cable.

The IF preamplifier possesses the following advantages:

(1) low noise factor determined by the low noise factor of the first triode;

(2) stable operation, since the first stage has a gain of about unity.

The IF signal is passed from crystal mixer ДГ-С4 (Д2-1) to the grid of valve 6Ж1П (Л2-13) through inductively coupled windings of circuit L2-10 and L2-11.

Coils L2-12, L2-13, L2-14 and capacitors C2-44, C2-45, C2-46, C2-47 constitute filters in the crystal current circuit.

Capacitors C2-44, C2-45, C2-46, C2-47 decouple this circuit from the high-frequency currents.

The signal amplified substantially in power by valve 6Ж1П (Л2-13) is fed through isolating capacitor C2-50 to the cathode of grid-earthed triode 6Ж1П (Л2-14). The coil in the anode of valve Л2-13 serves as a load.

The first valve Л2-13 is neutralized by inductance coil Л2-16 tuned together with grid-anode capacitance. The use of neutralizing improves the noise factor by 0.25 db. The cathode-anode capacitance of grid-earthed triode Л2-14 is sufficiently large (3.1 picofarads) and is neutralized by inductance coil L2-32 resonating with this capacitance. The signal from the anode of valve Л2-14 is coupled through isolating capacitor C2-55 to the control grid of valve 6Ж1П (Л2-15) of the normal pentode amplifier operating into a

90-ohm radio-frequency cable. The circuit of the valve grid is tuned to a frequency of 33 Mc/s, while the anode circuit of this valve (L2-21), to a frequency of 27 Mc/s.

Resistor R2-43 is the anode load of valve Л2-15. Connected into the anode circuit of valve Л2-15 is coil L2-21 which together with isolating capacitor C2-56 and resistor R2-44 with radio-frequency cable serve to match the IF preamplifier with the main IF amplifier.

The bias voltage on the control grids of valves Л2-13 and Л2-15 is automatic on account of the voltage drop across resistors R2-38 and R2-46. Capacitors C2-48 and C2-58 block these resistors.

The anode circuits of valves Л2-13 and Л2-15 contain filters formed by resistors R2-39, R2-40, R2-42 and blocking capacitors C2-52, C2-53, C2-54. The valve anodes are supplied with 140 V from supply unit Д-8.

The filaments are connected in parallel and fed with 6.3 V A.C. being applied from filament transformer Tp2-9. Chokes L2-17, L2-18, L2-20 with capacitors C2-49, C2-90, C2-57 perform the function of high-frequency decoupling filters in the filament circuits of the valves.

The IF preamplifier has the following characteristics:

1. Amplification factor of IF preamplifier $K \geq 10$.
2. Passband at 0.7 level $2\Delta f \geq 6$ Mc/s.
3. Mid-frequency of IF preamplifier $f = 30 \pm 0.5$ Mc/s.

Klystron AFC system

The AFC system of the klystron is designed for automatic control of the klystron frequency so that the intermediate frequency may remain equal to $f_{int} = 30$ Mc/s upon variation of the magnetron frequency.

The AFC and search system consists of an IF amplifier, frequency detector (discriminator), video amplifier, blocking oscillator and control valve (See Fig.28).

The output of the AFC system mixer is applied to the two-stage IF amplifier using valves 6Ж1П (Л2-16, Л2-17).

The amplifier input uses an autotransformer circuit. Coil L2-22 and capacitor C2-64 constitute an input circuit. Resistor R2-47 serves to widen the passband of the input circuit. Coil L2-26 and input capacitance of valve Л2-17,as well as the spurious capacitances, constitute an input filter of the second stage.

Connected into the anode circuit of valve Л2-17 is the primary winding of the frequency detector transformer (L2-27). Coil L2-28 is coupled with coil L2-27 by weak indicative coupling and,capacitively, through C2-71 (See Fig.29). Choke L2-29 serves to pass D.C. of dual diode, 6x6 (Л2-18), and to block A.C. Capacitors C2-75 and C2-76 are blocking capacitors. Their capacitive resistance to IF currents is very small; therefore there is no A.C. component of the potential to chassis on the dual diode cathodes. The output voltage of the frequency detector is taken from the common resistance jack Г2-3 (cathode 8 of Л2-18) consisting of two resistors P2-55 and R2-56 carrying D.C. currents of both halves of dual diode Л2-18 in opposite directions.

From Fig.29 it is seen that each anode of dual diode Л2-18 is fed with alternating voltage consisting of the sum of two voltages; the first voltage is applied from the primary circuit of the transformer through capacitor C2-71, and the second is equal to half, the voltage being developed in the secondary circuit. Since the quality factor of the primary circuit is comparatively small (due to shunting action of resistor R2-52), then near the intermediate frequency the magnitude of the primary circuit voltage being applied to the anodes of valves Л2-18through capacitor C2-71 will not change practically.

The magnitude and phase of the secondary circuit voltage on each of the anodes of diode Л2-18 depend upon the frequency of the input signal.

From Fig.29 it is evident that the primary circuit voltage is supplied in phase through capacitor C2-71 to the anodes of the diode, while the secondary voltage, in anti-phase.

It is well known that at frequency (30 + 0.3) Mc/s near to the resonance one, the resistance of the secondary circuit is actually an active resistance; in this case, the voltage across the secondary winding is shifted in phase by 90° with respect to the primary winding voltage. Based on this the vector diagram of Fig.30 is considered true. The designations on the diagram mean the following:

- U_1 - voltage vector of primary circuit;
- $\frac{1}{2}U_2'$ - half the vector of secondary circuit voltage applied to anode 3 of diode, 6Х6 (Л2-18);
- $\frac{1}{2}U_2''$ - half the vector of secondary circuit voltage applied to anode 5 of diode, 6Х6 (Л2-18);
- U_3 - vector of voltage applied to anode 3 of diode;
- U_5 - vector of voltage applied to anode 5 of diode.

From the vector diagram it is seen that the voltages applied to anodes 3 and 5 of diode 6Х6 are equal; as a result, the currents of both portions of the dual diode are equal, and as they oppose each other, the output voltage of the frequency detector is zero.

With a frequency exceeding (30 + 0.3) Mc/s the resistance of the secondary circuit is of the inductive nature and the vector diagram will have the form shown in the figure.

From the diagram it is seen that voltages U_3 and U_5 applied to anodes 3 and 5 of diode 6Х6 are unequal and the output voltage of the frequency detector is other than zero.

With a frequency below (30 + 0.3) Mc/s, the resistance of the secondary circuit is of the capacitive nature and the vector diagram will have the form shown in Fig.30,c.

Voltages U_3 and U_5 applied to anodes 3 and 5 of diode 6Х6 are unequal and the output voltage of the frequency detector is other than zero.

From the vector diagrams considered it is seen, that the phase relationships between the voltages of the primary and secondary circuits are such that at frequency (30 + 0.3) Mc/s the resulting voltages on the anodes of the frequency detector are equal, while at a frequency exceeding (30 + 0.3) Mc/s the resulting voltage applied to anode 3 of the left diode increases, and at a frequency below (30 + 0.3) Mc/s the resulting voltage applied to anode 5 of the right diode increases, as well.

Thus, a pulse appears across frequency detector load resistors R2-55, R2-56 the magnitude and sign of which depend upon departure of the intermediate frequency from (30 + 0.3) Mc/s. Since the given AFC circuit is operated by the positive pulse, the characteristic of the frequency detector (discriminator curve, See Fig.31) is asymmetrical. This is achieved by inserting resistor R2-80 in the anode of the left portion of valve Л2-18.

The point where the discriminator curve passes zero differs by 0.3 Mc/s from intermediate frequency 30 Mc/s so that the pulse may be communicated to the control valve (right portion of valve Л2-20 when the intermediate frequency is precisely 30 Mc/s.

The pulses from the frequency detector output are supplied to a two-stage video amplifier - valve Л2-19 (6H8C). Variable resistor R2-57 changing the video amplifier gain serves for setting the required level of the output voltage of the AFC system. Positive pulses from the anode of the right portion of valve Л2-19 are coupled to the grid of the control valve - the right portion of valve Л2-20 (6H8C) operating as a grid detector. These pulses decrease the anode current through the valve, thereby increasing the negative voltage being applied to the klystron repeller. The anode current of the control valve is the smaller, the larger is the amplitude of the positive pulses coming from the anode of the right portion of valve Л2-19, i.e. the larger is the IF drift from the rated value. In this case, as a result of the negative voltage rise on the repeller, the klystron changes the frequency being generated, owing to which the rated intermediate frequency is obtained. This is the way how the intermediate frequency is maintained constant within the working section of the discriminator curve. If the intermediate frequency changes substantially (beyond the range of the working section of the discriminator curve), positive pulses will not arrive at the control stage.

For this reason the anode current will grow through the right portion of valve Л2-20; this will result in a decrease of the negative voltage on the cathode of the control valve, and on the grid of the cut-off blocking oscillator (left portion of valve Л2-20) coupled to it through chain R2-66, C2-81. The blocking generator starts producing pulses which are taken from cathode 3 of valve Л2-20 and after being differentiated by chain C2-80, R2-64, R2-62 and R2-63 are fed to the grid of the second stage of the video amplifier (right portion of valve Л2-19) replacing the pulses from the frequency detector. Positive pulses are clipped by the grid currents, while negative after amplification are passed from anode 5 of valve Л2-20 in the form of positive pulses to the grid of the control valve. The negative voltage at the AFC output begins increasing changing correspondingly the grid voltage of the blocking oscillator. As the time constant of chain R2-66, C2-81 is large enough, the voltage on grid 1 Л2-20 of the blocking oscillator varies slowly and the voltage at the AFC output has the time to vary substantially (by some dozens of volts). This gives simultaneous rise to the negative potential on the grid of the blocking oscillator and the latter stops oscillating. After the blocking oscillator oscillations are stopped, its pulses are not furnished to the grid of the control valve and the negative voltage at the AFC output starts decreasing until the blocking oscillator is made conductive again, and so on. At the moment the intermediate frequency coincides with its rated value, the AFC circuit is returned automatically to control operation, since the blocking oscillator is cut off at this moment.

Variable resistors R2-67 and R2-68 determine the operating conditions of valve Л2-20. They can be used for varying the frequency, amplitude and range of the search voltage at the AFC output.

3. Receiver Д-3

Purpose

Unit Д-3 is a component part of the main receiver and sighting receiver of station K-IIM. It amplifies the IF signals produced by the receivers and converts these signals in target and sighting video pulses passing them to the indicators and automatic tracking system of the station. Besides, the unit ensures automatic level control of the picked-up target signals and blocks the receivers at the start of each operation cycle of the station, thereby eliminating the harmful effect produced by the leaking of the main pulse.

Unit composition

According to the functions performed the unit components may be considered under the following headings:

(a) IF amplifier of main channel amplifies the IF signals (30 Mc/s).

(b) Second detector of receiver main channel converts the IF signals into video signals.

(c) Video amplifier of main channel amplifies the target video amplifier to the level required for normal operation of the tracking system and plan position indicators of the station.

(d) Video amplifier of main channel indicators ensures transmission of the target signal to the plan position indicators of the station and separation of the tracking and plan position indicator video circuits with a view to removing coupling between these circuits.

(e) AGC detector is part of the AGC circuit of the main channel receiver. The circuit produces D.C. voltage proportional to the level of the selected signal.

(f) AGC amplifier ensures obtainment of the required level of the D.C. control voltage in the automatic gain control circuit.

(g) IF amplifier of sighting channel amplifies the IF (40 Mc/s) signals produced by the mixer of the sighting receiver.

(h) Second detector of sighting channel converts the IF signals into sighting video signals.

(i) Video amplifier of sighting channel amplifies the signals to the level required for operation of the sighting indicator of the station.

(j) Disabling pulse multivibrator produces pulses disabling the main channel and sighting receivers when the transmitter fires the main pulse.

Description of schematic diagram

The schematic diagram of the unit is shown in Fig.32. The upper part of the diagram is occupied by the IF amplifier, second detector and video amplifier of the main channel. Shown in the middle are the disabling pulse multivibrator, detector and AGC amplifier. In the lower part of the diagram are shown the IF amplifier, second detector and video amplifier of the sighting channel. From the IF preamplifier of unit Д-2M the IF signal is communicated to the valve grid of the first IF amplifier. Resistor R3-1 is connected for matching the cable and equals its characteristic impedance (91 ohms). All the six stages of the IF amplifier of the main channel connected as an oscillatory circuit into the grid circuit of the next valve. In this case anode resistors R3-4, R3-7, etc., shunt the circuits ensuring obtainment of the required quality factor. The circuit capacitors of the stages consist of the input and output capacitances, valve capacitance, wiring capacitance, capacitance of the valve sockets and interturn capacitance of coils L3-2, L3-4, etc.

The circuits of the first, third and fifth stages are tuned to frequency (30 + 3) Mc/s. The circuits of the second, fourth and sixth stages are tuned to frequency (30 - 3) Mc/s.

By detuning the tuned circuits with respect to IF it is possible to obtain a 6 Mc/s passband of the entire amplifier.

The negative-going disabling pulse is furnished to the grid of Л3-1 through the high-frequency filter and voltage divider R3-3, R3-2. Capacitor C3-1 prevents short-circuiting of the disabling pulse across the low-resistance circuit of the amplifier input, capacitor C3-2 improving the pulse shape.

Resistor R3-5 serves to obtain automatic bias on the grid of valve Л3-1. Capacitor C3-4 blocks this resistor for high frequency. Filtering circuit R3-6, C3-5 cancels parasitic feedback through the anode circuits of the first and second stages of IF amplifier (valves Л3-1, Л3-2). Capacitor C3-6 protects the control grid of valve Л3-2 against high voltage on the anode of valve Л3-1.

The purpose of similar components of other IF amplifier stages is analogous. Each stage raises the IF signal level approximately six times. The gain of the entire amplifier makes up 35,000.

The gain of the main channel receiver is controlled by feeding the grids of the second (Л3-2) and third (Л3-3) stages with negative voltage (relative to the valve cathodes) from the AGC and MGC circuits. Filters R3-9, C3-7 and R3-13, C3-12 cancel spurious feedback through the gain control circuit.

The amplified signal is detected by the diode detector (Л3-7) whose circuit includes: oscillatory circuit of the sixth IF amplifier stage L3-12, valve 6Ж1П connected as a diode, and load resistor R3-24.

Connection of coil L3-12 into the cathode of valve Л3-7 causes negative-going video pulses to appear across the detector load. Capacitor C3-30 slightly increases the detector conversion factor equal to 0.52. Choke L3-13 prevents penetration of radio-frequency energy obtained during detection to the video amplifiers. Jack 2 is used only when tuning the unit for measuring the amplification factor and taking frequency characteristics of the amplifier.

The video signals produced by the detector are furnished through isolating capacitor C3-31 to the grid of the first video amplifier stage (Л3-8), amplified and passed further to the output cathode follower (Л3-9) employing valve 6Н1П. The anode of valve Л3-8 contains inductance coil L3-14 to improve the video amplifier frequency characteristic in the region of hight frequencies.

Valve Л3-8 operates with a slight bias on the control grid, the bias being built up by automatic voltage drop across resistor R3-25. This provides the required amplification of the negative-going pulse.

Double capacitor C3-32 blocks the anode and cathode circuits of valve Л3-8.

Provision of a cathode follower (Л3-9) in the video amplifier is necessitated by further conveying signals over the low-resistance cable to unit Д-7. The cathode follower enables the amplifier to be matched with the cable due to comparatively low output resistance (approximately 100 ohms). R3-30 is the gridleak of valve Л3-9 and R3-32 is the cathode follower self-bias resistor. Filter R3-31, C3-35 cancels spurious feedback through a +300-V rectifier supplying the amplifier. Test jack 3 is used for passing pulses to the amplifier input when adjusting the unit.

The main channel video amplifier transfers the signal onto the selector stage of unit Д-7 to the input of the video amplifier of the indicators. The video amplifier, which uses valve 6H1П (Л3-12) in a cathode follower circuit, ensures transmission of the signal over the coaxial cables to units Д-4М, Д-5 and separates video channels of the tracking system and indicators with a view to removing coupling between these channels.

In the diagram C3-47 is the isolating input capacitor; R3-49, the gridleak of valve Л3-12; C3-48, R3-50, the decoupling anode filter; R3-51, the self-bias resistor and C3-46, the isolating output capacitor.

The automatic gain control AGC circuit of the main channel receiver consists of an AGC detector (left portion of valve Л3-13) and AGC amplifier (right portion of valve Л3-13). The anode circuits of the AGC detector and AGC amplifier are supplied by the rectifier developing a negative voltage of -255 V relative to the unit chassis. This provides obtainment of the AGC negative voltage controlling the IF amplifier gain. The left portion of valve Л3-13 operates as an anode detector with load R3-54 connected to the valve cathode. Negative bias to the detector grid is supplied from voltage divider R3-53, R3-55, R3-59 for obtaining the AGC delay.

The AGC delay is controlled by potentiometer R3-53. Owing to the delay the AGC circuit starts functioning at a certain level of the received signal and is disconnected automatically in case of weak signals. The target signal of positive polarity is coupled to the input of the AGC detector through capacitor C3-54, from the selector of unit Д-7. Across R3-54, C3-50 the D.C. component of the detected signal is separated and through resistor R3-58 is passed to the control grid of the AGC amplifier. The amplified D.C. voltage is separated across resistor R3-56, filtered by R3-57, C3-51 and is applied to the valve grids of the second and third stages of the main channel IF amplifier. To this circuit may be connected a voltage divider located on the control panel of the station when manual gain control is resorted to. Connection of the MGC paralyses the AGC action.

This is because the low-resistance MGC potentiometer shunts high resistance AGC circuits (R3-57). The time constant of the AGC circuits determines the receiver ability to keep constant the level of video pulses at the output at various rates of changing the picked-up signals. The time constant in the circuit under consideration is mainly determined by the values of R3-54, C3-50 and is taken equal to 0.25 sec.

With these characteristics the receiver AGC does not demodulate the signal whose level changes due to scanning of the antenna dipole at frequency Ð c.p.s. and slowly varies the signal power conditioned by interference. The AGC range is 60 db at the 22-V signal level at the receiver output.

The IF amplifier of the sighting channel differs from that of the main channel only in electrical characteristics. It is also composed of six single IF amplification stages employing miniature pentodes 6Ж1П (Л3-14, Л3-15, Л3-16, Л3-17, Л3-18, Л3-19) with tuned circuits connected into the valve grids of the subsequent valves. The circuits of the first and fourth stages are tuned to frequency (40 + 5) Mc/s; the circuits of the second and fifth stages are tuned to frequency (40 - 5) Mc/s, the circuits of the third and sixth stages are tuned to 40 Mc/s. The adopted system of tuning the circuits to three different frequencies ensures a passband of the entire amplifier equal to 10 Mc/s and amplification factor to 7000.

The IF amplifier of the sighting channel is fed with signals from the IF preamplifier of unit Д-16 through a coaxial cable. The sighting video signals are discriminated by the diode detector Л3-20, which passes them to the cathode follower (Л3-21 and Л3-22).

The detectors and video amplifier of the sighting channel are similar to those discussed above. The conversion factor of the detector is 0.7 and amplification factor of the video amplifier is 15. The start-stop multivibrator (Л3-10) is triggered by positive pulses leading the main pulses by 1 microsec. This improves suppression of noise from the main pulse on account of radar time displacements of the main and suppressor pulses.

Before arrival of the trigger pulse the right triode Л3-10 is made conducting by +300 V being supplied to the valve grid through resistor R3-43. The anode current of this triode sets up a voltage drop across R3-41 driving the left triode to cut-off. When a positive pulse arrives at the grid of the left portion of valve Л3-10, a negative pulse cutting off the right triode through C3-42 appears on its anode. In this case the voltage drop across R3-41 becomes equal to zero and the left triode begins to conduct.

The right triode will be cut off until capacitor C3-42 discharges through resistor R3-43 to a potential approximately equal to the anode of the open left portion of valve Л3-10. After capacitor C3-42 has discharged the circuit comes back to the initial state, i.e., the right triode becomes conducting and the left triode is driven to cut-off.

The voltages in the circuit drop in an avalanche-like manner because of positive feedback between the stages. Owing to this condition the circuit produces disabling square pulses. The time constant of R3-43, C3-42 is so chosen that the length of the disabling pulse is approximately 0.5 microsec, which ensures overall covering of the noise pulse.

Potentiometer R3-38 makes it possible to change the trigger level of the left triode and thereby vary the duration of the disabling pulse when aligning the radar. From the anode of valve Л3-10 the disabling pulse is furnished through isolating capacitor C3-43 to the grid of valve Л3-11(6Ж1П).

This valve improves the shape of the disabling pulse by clipping the positive peak, limits the amplitude of the disabling pulse and reverses its phase. Valve Л3-11 operates with a large negative bias on the control grid produced by the voltage divider R3-48, R3-47, R3-46 - the anode load resistance of valve Л3-11, R3-45, C3-44 - the decoupling anode filter.

From the anode of valve Л3-11 the disabling pulse is passed to the grids of the first IF stages of the main and sighting channels through a RF filter.

The unit supply: the filament circuits of the valves are fed by transformer Tp3-1 incorporated in the unit; in this case, valve Л3-13 is connected to an individual unearthed winding.

The anode circuits of both IF amplifiers are fed with unstabilized voltage of +140 V; the output cathode followers and disabling pulse multivibrator are fed by the +300-V rectifier.

The unit consumption: 0.45 A from 117 V, 400 c.p.s. supply source
-30 mA from +300-V rectifier
-150 mA from +140-V rectifier
-3 mA from -225-V rectifier.

4. Sweep Unit Л-4M

Purpose

The sweep unit is designed to:

(a) Shape the saw-toothed current feeding the rotating coils of the search indicator.

(b) Square the search sweep brightening pulse.

(c) Shape the trigger pulse of the search sweep generator, when the unit is triggered by external pulses.

(d) Obtain calibration range markers used for determining the target range.

(e) Mix signals: target, range mark, heading marker, calibration range markers, and present these signals for intensity modulation of the search indicators when sweep is on its forward stroke.

(f) Mix signals: reply signals, target selection pulse and calibration markers for amplitude modulation of A-display of the sighting indicator.

(g) Shape the saw-toothed sweep voltage of the target tracking indicator.

(h) Form positive square-wave voltage of sweep brightening on the screen of the target tracking indicator.

The unit consists of five component parts designed as three individual subpanels.

Oscillator and search sweep amplifier comprise the 1st subpanel (left); marker oscillator and search channel mixer form the 2nd subpanel (middle).

Sighting indicator mixer, saw-toothed voltage forming channel of the tracking indicator and shaping stage for triggering search sweep generator from external sources make up the 3rd subpanel (right).

Description of functional and schematic diagrams of sweep unit

The diagram includes twenty-five elements of which:

1. Forming stage, 2. Buffer amplifier, 3. Sweep limiter, 4. Multivibrator , 5. Saw-toothed wave generator, 6. Saw-toothed voltage amplifier of operator's indicator, 7. Saw-toothed voltage amplifier constitute the search sweep channel.

8. Buffer amplifier, 9. Forming stage, 10. Oscillator, 11. Blocking oscillator, frequency divider of calibration range markers constitute the calibration marker oscillator.

12. Calibration marker cathode follower, 13. Range marker cathode follower, 14. Video amplifier, 15. Output stage constitute the mixer.

16. Calibration marker amplifier, 17. Calibration marker cathode follower, 18. Target selection pulse cathode follower, 19. Reply signal cathode follower constitute the mixer of the sighting indicator.

20. Trigger pulse cathode follower, 21. Multivibrator, 22. Saw-toothed wave generator, 23. Cathode follower, 24. Brightening pulse cathode follower of the tracking indicator constitute the saw-toothed voltage channel of the tracking indicator.

The schematic diagram of the unit is shown in Fig.34.

The sweep unit consists of five component parts:

1. Oscillator and search sweep amplifier.
2. Calibration marker oscillator.
3. Mixer.
4. Mixer of sighting indicator.
5. Saw-toothed wave generator of tracking indicator.

Oscillator and search sweep amplifier

The unit is fed from unit Д-7 (resistor R7-166 of valve Л7-9) with positive-going, short-time pulses of 40 - 45 V amplitude through cable 28. These pulses trigger the search sweep circuit.

The search sweep circuit consists of a buffer amplifier, sweep trigger multivibrator, sweep limiter or quenching valve, sweep generator , sweep amplifier and diode restorer. The block diagram of the oscillator and search sweep amplifier is shown in Fig.35. An additional element of the search sweep channel is the forming stage to trigger the sweep from external sources, which is switched on when changing for checking the station operation.

Sweep trigger forming stage

The forming stage serves to trigger the search sweep channel by positive and negative pulses of some 15 V from external sources. In this case, switch B4-2 must be set at CHECK.

In view of the majority of the pulses used for external triggering having large parasitic peaks, the right half of valve Л4-15 is driven to "minimum" limiting, for which purpose its grid is biased negatively. This clips the peaks by an amplitude of 10 - 12 V.

If triggering is effected by a positive pulse, the pulse is furnished from jack Γ_4-1 to control grid 1 through capacitor C_4-41 and is picked off negative from anode 2 through capacitor C_4-44 to grid 4.

If the trigger pulse is negative, it is supplied from jack Γ_4-6 to cathode 3.

The other half of valve Л4-15 (grid 4, anode 5, cathode 6) amplifies the trigger pulse to 40 V and turns it over. The pulse is fed to trigger the sweep of the search channel.

Buffer amplifier

The first portion of valve Л4-1 (6Н9С) is the buffer amplifier whose grid is fed with positive trigger pulses: the amplifier cathode is kept at some +12 V. This voltage is taken from a divider formed by R4-2 and R4-3. With such a bias the valve is driven to cut-off. The positive trigger pulse being applied to the grid is greater in amplitude than the bias, and the valve is driven into conduction. The anode potential drops sharply. As a result, a negative pulse is obtained at the stage output. The shape and polarity of the input and output pulses is shown in the block diagram of the oscillator and sweep amplifier (Fig.35).

Sweep trigger multivibrator

The negative pulses from the buffer amplifier start the sweep trigger multivibrator. The simplified diagram of this multivibrator is shown in Fig.36.

The multivibrator employs two triodes of valve Л4-2 (6Н8С). Before arrival of the trigger pulse the second triode of the valve (grid 4, anode 5, cathode 6) is conducting, since grid 4 is connected to +300-V supply through resistor R4-11, which causes the appearance of the grid current. The cathode resistor carries a current large enough to raise the cathode potential with respect to the grid potential. That is why the triode operates near the zero bias.

The first triode of valve Л4-2 (grid 1, anode 2, cathode 3) is cut off. Its grid is fed with a positive bias of about +14 V (the voltage drop caused by +300-V supply across resistors R4-67 and R4-4); at the same time a large negative bias is fed from resistors R4-97, R4-9 and R4-10 through which the anode current of the second triode flows.

Upon arrival of the negative pulse from the buffer amplifier, the anode current of the second triode stops flowing through resistors R4-97, R4-9 and R4-10, and the second triode is cut off. As a result, the negative bias is taken from grid 1, the first triode begins conducting. The anode potential of the first triode drops and the resulting negative pulse on grid 4 keeps the second triode cut-off. The second triode might be open upon discharge of capacitor C4-3. The capacitor discharge depends on the time constant of RC (C4-3 and R4-11), but the triode is driven into conduction before capacitor C4-3 manages to discharge. This is because grid 1 is fed with a strong "finalling" negative pulse from the sweep limiter (auto-quenching valve).

The anode potential of the first triode rises, grid 4 receives sufficient positive bias and the second triode starts conducting.

Thus, the trigger multivibrator shapes a negative square pulse (on the anode of the first triode), whose beginning is time-coincident with that of the trigger pulse, and the end is determined by the pulse from the sweep limiter. The waveform and polarity of the pulses are shown in Figs 36 and 37.

Sweep limiter (auto-quenching valve)

The simplified circuit diagram of the sweep limiter is presented in Fig.37.

Valve Л4-1 (grid 4, anode 5, cathode 6) of the sweep limiter is started by a positive saw-toothed pulse, taken from feedback resistors R4-24 and R4-25 of the sweep amplifier.

Before arrival of this pulse the triode is cut off by the bias voltage (on the triode cathode) taken from resistor R4-9. As the positive saw-toothed pulse arrives from the feedback resistors of the sweep amplifier, the potential of grid 4 rises. When it exceeds the positive bias on the cathode, the triode becomes conductive.

The trigger potential is set by means of rheostat R4-9. When the triode is triggered, its potential on anode 5 drops and cuts off (stops) the first triode (grid 1, anode 2, cathode 3) of the sweep trigger multivibrator. As a consequence, the triode (sweep limiter valve) is cut off momentarily, for the trigger multivibrator will stop the saw-toothed wave generator and this will restore the initial negative bias on grid 4 of the triode with respect to cathode 6.

Sweep generator

The sweep generator valve Л4-3 (6Н9) has no cathode load. Its grid is coupled to the unit chassis through resistor R4-12. This valve is a well-conducting valve. At the moment its grid is fed with a negative pulse, the valve gets cut off, the anode potential begins rising at the rate depending upon the rate of charge of capacitor C4-5 through one of the sweep rate-determining resistors R11-37, R11-58, R11-39, R11-57 located in the control panel. By operating the range selector on the control panel resistance is selected (for each range) of such a value that the RC time constant may produce the wanted rate of sweep. Upon cessation of the negative square pulse valve Л4-3 becomes triggered again and its anode potential falls sharply. As a result, a saw-toothed voltage is obtained, which is fed to the grids of the sweep amplifiers of the operator's and remote indicators.

The output voltage on the screen grid of the sweep generator has the form of positive square pulses. They are obtained, in this case, due to absence of the earth-shunting capacitor. The pulses are used for brightening the search sweep trace.

The sweep generator, the waveform and polarity of its pulses are shown in Fig.38.

Sweep amplifier

The saw-toothed voltage from the sweep generator is fed to two similar three-stage amplifiers located one in the operator's indicator, the other - in the remote indicator. The simplified circuit diagram of the sweep amplifier of the operator's indicator is presented in Fig.39 (this amplifier is under consideration).

The first stage employs the first triode of valve Л4-4 (grid 1, anode 2, cathode 3) and is actually a normal voltage amplifier. The triode grid is directly coupled to the anode of the sweep generator. This results in appearance of positive bias on the grid, but the anode potential of valve Л4-3 is so low between the sweep pulses that the bias from resistor R4-23 turns to be sufficient for keeping this grid at a low negative potential.

When the sweep is on its forward stroke, the potential of cathode 3 of valve Л4-4 rises maintaining a negative bias on grid 1.

The sweep amplitude is varied by the rheostat (R4-25) in the cathode circuit entitled AMPLITUDE OF OPERATOR'S INDICATOR SWEEP (АМПЛИТУДА РАЗВЕРТКИ ИНДИКАТОРА ОПЕРАТОРА).

The first stage (valve Л4-4 of the sweep amplifier operates as a variable-gain amplifier.

Setting of rheostat R4-25 has no effect on the amplitude of the voltage being applied to the sweep limiter.

If, for instance, the value of R4-25 is decreased, the gain of the sweep amplifier increases due to a decrease of negative feedback. Resistor R4-25 handles greater current and the voltage drop across the resistor remains invariable. This means that the steepness of the sweeping voltage and, consequently, the amplitude can be changed without changing the duration of the saw-toothed voltage.

The second stage of the sweep amplifier employs the second triode of valve Л4-4 (grid 4, anode 5, cathode 6). It has no resistor in the cathode circuit and operates as a normal amplifier with the anode load and gridleak for partial D.C. restoration. Capacitor C4-9 blocks the D.C. component of the saw-toothed voltage.

The remaining A.C. component is applied to the grid and produces equal areas above and below the mean value of the zero potential line. During the resting time the grid starts acquiring a negative potential, but the grid current that has appeared passes through resistor R4-19 and feeds negative bias to the grid.

During the resting time the capacitor discharges slightly, which is conditioned by the time constant of resistor R4-19 and capacitor C4-9. This provides for operation of the second triode of valve Л4-4 irrespective of the amplitude of the sweep pulses or duration of intervals between them.

The third (output) stage of the sweep amplifier employs valve Л4-8.

Its cathode is earthed through deflecting coil of the indicator and resistor in the cathode circuit of the first stage. The anode current of the last stage builds up a voltage in the cathode circuit of the first stage of the polarity, which causes increase of bias in the first stage. The injected negative bias stabilizes the gain and linearity of the sweep.

Before the sweep starts valve Л4-8 is cut off, since it has a bias 27 V less than the cut-off voltage. The amplifier (valve Л4-4) operates without negative feedback and gives a high gain. Owing to this the saw-toothed voltage becomes steeper, the sweep speeds up considerably and the loss of time required for raising the potential from the value at the cut-off valve to the value at the open valve is only 0.5 microsec. After the valve is open the negative feedback reduces the overall gain. The sweep rate decreases the value required for the distance range used.

Action of the negative feedback is shown in Fig.40.

Section AB is below the cut-off bias of valve Л4-8 and is amplified greatly by the two first stages.

Section BC is the operating section of the sweep at which a current flows through the deflecting coils. This develops a negative feedback decreasing the gain. This section is less steep than section AB.

After every pulse, the current through the sweep coils must be zero. This is necessary to allow the spot to return to the screen centre before commencement of the next sweep pulse. If there is current during the resting time a circle is obtained in place of the bright spot in the screen centre, i.e., the start of the sweep is off-centred.

To prevent direct current between the sweep pulses a constant bias of - 52 V on valve Л4-8 is sufficient.

To eliminate jumping of range marks on the remote indicator, potentiometer R4-20 is introduced into the second stage of the search sweep amplifier.

Diode restorer

Placed between the second and the final stages of the sweep amplifier is diode Л4-6. Its function is to restore the D.C. component on the grid of the output stage. This is necessary to make the instantaneous value of the grid potential of valve Л4-3 dependent only upon the impressed saw-toothed voltage and independent of the waveform of this voltage.

If this is not so the amplitude of the sweep on the indicators would vary with the range scale used. The functioning of the diode restorer is shown in Fig.41.

The left part of the illustration shows the case when there is no diode restorer before the output stage. Two cases are referred to when the grid of the output stage is fed with saw-toothed voltage with equal amplitude of 40 V, but with different lengths of the saw-toothed wave.

Grid 5 of valve Л4-7 and Л4-8 is fed with bias voltage of 72 V from the -225 V supply via voltage divider R4-39 and R4-38.

When the saw-toothed voltage passes through the coupling circuit (C4-12, R4-34, R4-35, R4-38) not containing diode Л4-6 to the grid of valve Л4-8, it will be displaced with respect to the fixed bias level of 72 V so that the saw-toothed areas above and below the bias level line are equal. However, in consequence of different lengths, the saw-toothed wave amplitude will vary, in one case, from -82 V to -42 V, and, in the other case, from - 76 V to -36 V, i.e., in one case, the saw-toothed wave amplitude with respect to the 72-V level is 30 V, and in the other case is 36 V. This means that the operating point of valve Л4-8 will be displaced depending on the duration of the saw-toothed voltage and the sweep on the PPI screen will not start from the same point at various range scales, while the sweep amplitude will be the larger the shorter the sweep duration and vice versa.

To prevent displacement of the operating points of valves Л4-7 and Л4-8 at various range scales, use is made of the diodes of valve Л4-6 designed for D.C. restoration on the grids of valves Л4-7 and Л4-8.

The operating principle of the diode consists in the following: passage of the saw-toothed voltage causes capacitor

C4-12 to change to a potential determined by the duration of the saw-toothed wave and time constant of the RC circuit formed by C4-12, R4-35, R4-36, R4-38, R4-27. In this case, the time constant of the RC circuit is large.

Upon cessation of the saw-toothed voltage, a negative voltage corresponding to the charge of capacitor C4-12 will be applied to the diode cathode. This results from the potential difference between the capacitor plates not being in position to change instantly. Diode 6X6C will be driven into conduction and capacitor C4-12 will discharge through the diode over the circuit with a smaller time constant. Thus, the initial level of bias voltage equal to -72 V will be set on the grid of the output valve by the beginning of the next saw-toothed wave.

So, with any duty cycle of the saw-toothed wave, the bias level of output valve Л4-8 is maintained constant.

Calibration marker generator

The marker generator produces markers appearing on the indicator screen 10, 20 or 40 km. apart depending upon the position of knob RANGE, KM. (ДАЛЬНОСТЬ, КМ) on the front of the control panel.

The first marker appears at the moment when the trigger pulse arrives, the second, third, fourth, fifth and sixth markers (the fifth interval between the markers) will settle in line with the duration of the negative square pulse at the input of the calibration marker generator channel.

Owing to the sweep the range markers on the indicator screens look like bright circles. The latter are used as distance scales when range is to be read off.

The calibration marker generator circuit begins at divider R4-6 and R4-7 and ends at grid 1 of mixer valve Л4-11.

The calibration marker generator consists of a buffer amplifier, forming stage, sine-wave oscillator and blocking oscillator with frequency division circuits. Fig.42 shows a simplified circuit of the calibration marker generator.

The negative square trigger pulse is communicated through capacitor C4-15 to control grid 1 of valve Л4-9.

Before arrival of the trigger pulse the first triode of valve Л4-9 (grid 1, anode 2, cathode 3) is conducting, since there is no bias on its grid. Therefore, the potential on anode 5 of valve Л4-9 and grid 1 of valve Л4-10 is low due to a voltage drop when the anode current passes through resistor R4-43. In this case, grid 1 of valve Л4-10 is fed with a voltage of about +90 V, and cathode 3 with some +160 V from a voltage divider formed by resistors R4-49, R4-51, R4-52. Therefore, grid 1 of valve Л4-10 is biased to about -50 V with respect to cathode - the triode is cut off. Grid 4 of valve Л4-9 is zero-biased with respect to cathode, since it is fed with +29 V from the +300-V supply via divider R4-42 and R4-44. +29 V is taken via divider R4-49, R4-51 and R4-52 from the 300-V supply. Thus, the triode of valve Л4-9 (grid 4, anode 5, cathode 6) is open.

As the negative trigger pulse arrives, the triode of valve Л4-9 (grid 1, anode 2, cathode 3) is cut off. The potential of anode 5 of valve Л4-9 and that of grid 1 of valve Л4-10 increases, the first triode of valve Л4-10 (grid 1, anode 2, cathode 3) begins to conduct, and the circuit generates oscillations. The oscillation frequency in the circuit is determined by the parameters of the resonance circuit connected between the cathodes of the second triode of valve Л4-9 and first triode of valve Л4-10.

The marker frequency produced by the oscillatory circuit is 14.984 Mc/s, which corresponds to a 10-km. range. The frequencies of 7.492 Mc/s - 20 km. and 3.746 Mc/s - 40 km. are obtained on account of the frequency of the 10-km. markers divided by the blocking oscillator - the second triode of valve Л4-10 (grid 4, anode 5, cathode 6).

The oscillations amplified by the first portion of valve

Л4-10 are taken from the secondary winding of the pulse transformer to the grid of the blocking oscillator - the second portion of valve Л4-10.

The frequency of the 10-km. markers are divided due to the blocking process in valve Л4-10. In this case on 10- and 50-km. sweep scales the blocking oscillator is operated by every positive pulse on its grid.

On the 100-km. sweep scale, relay $P_Л$4-1 is energized, which switches over the blocking oscillator discharge circuit C4-22, R4-45 to C4-22, R4-46, R4-70. The frequency is halved, i.e., valve Л4-10 (second triode) opens only when acted on by every second pulse from the oscillatory circuit.

On the 200-km. sweep scale relays $P_Л$4-1 and $P_Л$4-2 are energized. These relays connect discharge circuit C4-22, R4-125, R4-71 to the blocking oscillator. In this case, the frequency of the oscillatory circuit is divided by four, i.e., the valve is driven to cut-off only when acted on by every fourth pulse of the oscillatory circuit. Resistors R4-70 and R4-71 are designed for adjusting the discharge circuits on the 100- and 200-km. sweep scales. Through the second group of relay $P_Л$4-1 on the 10- and 50-km. sweep scales a cut-off voltage of -225 V is supplied to the control grid of valve Л5-12 of unit Д-5.

On the 100- and 200-km. scales the circuit between the control grid of valve Л5-12 and the -255-V supply is broken and the cut-off voltage is not supplied, as a result.

Mixer

The mixer is designed for mixing video signals, calibration range markers, heading markers, range markers and presenting these signals over the video channel of units Д-5 and Д-6М when the sweep is on its forward stroke.

The mixer consists of the following components:

1. Video limiter - the second triode of valve Л4-12 (grid 4, anode 5, cathode 6).

2. Cathode follower (calibration range marker channel) - the first triode of valve Л4-11 (grid 1, anode 2, cathode 3).
3. Cathode follower (range marker channel) - the second triode of valve Л4-11.
4. Cathode output stage - valve Л4-13).

Video limiter

The video limiter (the second triode of valve Л4-12) starts functioning when the video pulse builds up bias on cathode 6 equal to the valve cut-off bias.

From anode 5 video signals are passed to the grid of valve Л4-13 through capacitor C4-33.

Cathode follower (calibration range marker channel)

Calibration range marker signals are applied to the first triode of valve Л4-11, followed in cathode 6, picked off resistor R4-60 common for the three stages of the mixer, to grid 4 of valve Л4-13. Resistor R4-54 serves to control the amplitude of the calibration markers by varying the negative bias on the cathode-follower grid.

Cathode follower (range marker channel)

The range marker signal is applied to grid 4 of the second triode of valve Л4-11 through capacitor C4-27. Then it is followed in cathode 6, taken from resistor R4-60 common for the three mixer stages and is communicated to grid 4 of the cathode follower (valve Л4-13).

The range marker brightness is controlled by means of potentiometer R4-126.

Cathode follower (Л4-13)

All the signals mixed are applied to the grid of valve Л4-13.

The valve cathode is fed with a heading marker. The circuit handling the heading marker is shown in Fig.44.

The low-resistance output of this stage provides a low shunting effect of distributing capacitance of the cables running to the indicators (Д-5 and Д-6М).

The simplified circuit diagram of the mixer with the output stage is presented in Fig.43.

Sighting indicator mixer

The mixer is designed to mix calibration range markers, missile reply signals, selected target pulses and to transmit these signals to unit Д-5 when the sweep of the sighting indicator is on its forward stroke. The mixer of the sighting indicator consists of the following components:

1. Calibration marker amplifier – the first triode of valve Л4-14 (grid 1, anode 2, cathode 3).
2. Calibration marker cathode follower – the second triode of valve Л4-14 (grid 4, anode 5, cathode 6).
3. Selected target pulse cathode follower – the first triode of valve Л4-16 (grid 1, anode 2, cathode 3).
4. Missile reply signal cathode follower – the second triode of valve Л4-16 (grid 4, anode 5, cathode 6).

The simplified circuit diagram of the sighting indicator mixer is shown in Fig.45.

Calibration range marker amplifier

Before arrival of positive calibration range marker pulses at grid 1 of valve Л4-14 the amplifier control grid is biased to about 12 V due to the voltage drop across resistor R4-74 in the cathode of the triode resulting from the passage of the anode current through the valve.

As the calibration marker pulses arrive at the grid, the first triode of valve Л4-14 opens sharply and the voltage on its anode 2 drops abruptly. Negative calibration marker pulses are passed through blocking capacitor C4-38 to grid 4 of valve Л4-14 (calibration marker cathode follower).

Upon cessation of the calibration marker, the first triode of valve Л4-14 comes back to its initial state.

The process is repeated with the arrival of the next calibration marker pulse.

Calibration range marker cathode follower

The calibration range marker cathode follower serves for transmission of signal and separation of the calibration range marker amplifier circuits and video channel of the sighting indicator.

The negative calibration range marker pulses come to grid 4 of valve Л4-14, followed in cathode 6 across resistor R4-78 and are passed to unit Д-5 over coaxial cable 12.

Selected target pulse cathode follower

This cathode follower serves for transmission of signals and separation of the circuits of unit Д-7 and unit Д-5.

The positive selected target pulse of about 25-V amplitude is applied to grid 1 of valve Л4-16, followed in cathode 6 across resistor R4-78 and is passed to unit Д-5 over coaxial cable 12.

Missile reply signal cathode follower

This cathode follower serves for transmission of signals and separation of the circuits of unit Д-3 and unit Д-5.

The positive missile reply signal of about 30-V amplitude is coupled to grid 4 of valve Л4-16, followed in cathode 6 across resistor R4-78 and is then furnished to unit Д-5 over coaxial cable 12.

Saw-toothed wave generator of tracking indicator

The saw-toothed wave generator is intended for producing the sweep on the tracking indicator of unit Д-5.

The tracking sweep generator consists of the following components:

1. Trigger pulse buffer stage (cathode follower - the second triode of valve Л4-17).
2. Driven multivibrator (Л4-18).
3. Saw-toothed wave generator (the first triode of valve Л4-19) and output signal cathode follower (the second triode of valve Л4-19).
4. Square brightening pulse cathode follower (the first triode of valve Л4-17).

The simplified circuit diagram of the saw-toothed wave generator of the tracking indicator is shown in Fig.46.

Buffer stage

The trigger pulse buffer stage employs the second triode of valve Л4-17 (grid 4, anode 5, cathode 6).

This stage behaves as a cathode follower. It separates the trigger circuit of unit Д-7 from the sweep circuits of the tracking indicator of unit Д-4М.

Driven multivibrator

The driven multivibrator employs valve 6Н8С. It functions in the same way as the multivibrator in the search sweep channel (valve Л4-2), the only difference being that the duration of the square pulse triggering the sweep generator is determined by the parameters of the multivibrator, by the discharge time constant of capacitor C4-56 in particular, rather than by an external turn-over pulse.

Saw-toothed wave generator and output signal cathode follower

The saw-toothed wave generator circuit is based on stabilization of the charging current by injecting the compensating EMF. Valve Л4-19, the first triode (grid 1, anode 2, cathode 3), performs the function of the generator proper, the second triode - cathode follower, conveying the output saw-toothed voltage to the second end of the discharge resistor (R4-109), thereby making the charging current constant.

This results in a linear saw-toothed voltage of a large amplitude at the generator output.

Resistor R4-110 forms a pedestal of saw-toothed voltage which compensates for the effect produced by the cable capacitance (about 300 to 850 pF), thereby providing linearity of the saw-toothed voltage at the beginning of the sweep.

Brightening pulse cathode follower

The brightening pulse cathode follower employs the first triode of valve Л4-17. The positive pulse from anode 5 of valve Л4-18 is applied to the cathode follower(half of valve Л4-17).

From the output of the cathode follower the positive brightening pulse (blanking signal ' ') is coupled through capacitor C4-53 to the tracking indicator of unit Д-5.

Current consumption

The current drawn by the unit from the power supplies must be:

(a) not more than 0.9 A from 115 V, 400 c.p.s. supply;

(b) not more than 100 mA from +350 V unstabilized voltage supply;

(c) not more than 110 mA from +300 V unstabilized D.C. voltage supply;

(d) not more than 35 mA from +300 V stabilized voltage supply.

5. Indicator Unit И-5

The indicator unit used in radar K-IIM is intended for viewing the position of targets in space scanned by the radar antenna. With regard to the purpose and operating modes of the radar, the indicator unit is comprised of three individual indicators. These are as follows:

(a) plan position indicator;

(b) tracking indicator;

(c) sighting indicator.

The plan position indicator is intended:

(a) to determine the range of a target or a group of targets;

(b) to determine the azimuth of a target or a group of targets;

(c) to determine the aircraft heading.

This indicator displays a circular sweep. The echo signal voltage is applied to the control grid of the cathode-ray tube. This increases the electron beam intensity during the pulse time. The result is that a bright spot indicating the azimuth of and distance to the target appears on the indicator screen.

The tracking indicator in radar K-IIM is intended for accurate target selection and viewing of automatic tracking of the selected target and targets within the field of vision of the antenna.

The tracking indicator has the L-display. This display is a modification of the A-display where two pulses reflected from the target are presented on the screen as peaks looking in opposite directions.

Schematic diagram of indicator unit Д-5

The schematic diagram of the indicator unit presents the channels of three indicators (Fig.47); therefore, the diagram will be analysed separately, channel by channel.

Plan position indicator channel

This consists of cathode-ray tube Л5-2, type 13ЛМ31, brightening pulse shaper and video amplifier - valve Л5-1, type 6H8C.

The equipment of the cathode-ray tube consists of:

(a) Rotary deflection coil L5-2.

(b) Selsyn motor M5-1, type СМС-1, rotating deflecting coil L5-2.

(c) Focusing permanent magnet with adjustable shunt.

(d) Centring system for vertical or horizontal displacement of the electron beam on the screen of the cathode-ray tube.

(e) Phasing contacts for synchronizing the deflection coil rotation with the antenna.

For protection of the cathode-ray tube against the effects produced by the external magnetic fields, its envelope is enclosed in a special screen.

The deflecting saw-toothed current is applied to deflection coil L5-2 from sweep unit Д4М.

The coil is coupled through selsyns to the gear rotating the deflection coil of the plan position indicator. The radial sweep trace rotates in synchronism with the antenna, and its direction at any time corresponds to the antenna direction.

High voltage to feed the cathode-ray tube is produced by the high-voltage rectifier located in unit Д25.

The tube brightness is controlled by varying the positive voltage on its cathode taken from potentiometer R5-9.

Resistors R5-106 and R5-10 determine the maximum (R5-10) and minimum (R5-106) brilliance of the tube.

The video signal which is actually a mixed signal composed of calibration markers, range markers, heading markers and echoes, is applied from the sweep unit to the cathode of the second triode of the search video amplifier (half of valve Л5-1), type 6H8C (See Fig.48).

RF correction is effected by coil L5-1, and AF correction, by resistor R5-7 and capacitor C5-3. The width of the amplifier passband is about 0.1 to 1.8 Mc/s. From the amplifier output (contact 5) the positive-going video signal is communicated to the grid of the cathode-ray tube. The cathode of the first triode of valve Л5-1 is fed from the sweep unit with the sweep trace brightening pulse which from the anode of this triode is passed to the first anode of the cathode-ray tube (contact 3), and from the divider formed by resistor R5-77, to the grid of cathode-ray tube Л5-14 (contact 3).

When the sweep length is varied from 335, 670 and 1340 microsec. the beam brightness of tube Л5-2 is almost invariable. When changing over to a sweep of 67 microsec. duration the beam brightness decreases more noticeably on account of the screen illumination time being reduced.

Tracking indicator channel

This consists of:

(a) Cathode-ray tube Л5-9, type 8Л029.

(b) Saw-toothed voltage buffer amplifier - valve Л5-8, type 6H8C.

(c) Tracking sweep brightening pulse buffer amplifier - half of valve Л5-3, type 6H9C.

(d) Switching video amplifier - valves Л5-4, Л5-6, type 6Ж4.

(e) Switching stage - valve Л5-5, type 6H9C.

(f) Brightening pulse shaper - valve Л5-10, half of valve Л5-8, type 6H8C, and half of valve 6H9C.

(g) Mixer - valve Л5-11, type 6H8C.

The cathode-ray tube (Л5-9) presents the L-display to find deviation of the target being tracked from the axis of the equisignal zone (See Fig.51). The duration of the tracking indicator sweep is 10 km. The start of the sweep may be displaced throughout the entire range of the radar. The sweep generator located in the sweep unit feeds unit Д-5 with positive saw-toothed voltage pulses (13th contact of connector ШВ5-1) and sweep trace brightening pulses (12th contact of connector ШВ5-1) at frequency n_2.

The saw-toothed voltage pulse is applied to plate Д-4 of tube Л5-9. Part of this voltage is fed to the grid of the buffer phase inverter amplifier with voltage negative feedback (capacitor C5-12) - valve Л5-8 (See Fig.49).

This amplifier employs two paralleled triodes, type 6Н8С; in addition to the divider (resistors R5-103, R5-46) the input contains correcting circuit C5-11, R5-103 which improves the linearity of the saw-toothed voltage. The negative saw-toothed voltage pulse having approximately the same amplitude as the positive pulse (200 V ± 10 per cent) is passed from the output of the buffer amplifier (resistor R5-44) to deflection plate Д-3 of tube Л5-9.

Thus, symmetrical deflection in range is effected.

The sweep trace brightening pulse coming from the sweep unit is applied to the cathode of the amplifier - half of valve Л5-3 (6Н9С) (See Fig.50). After being amplified the pulse is applied as positive to the grid of cathode-ray tube Л5-9 (contact 3).

Plates Д-1 and Д-2 are alternately supplied with video signals (connector Ф5-2) arriving from unit Д-3 (cable 45). The switchable amplifier (See Fig.52) serves for alternate supply of the video signals to plates Д3 and Д4.

The video signals are coupled to the control grids of two video amplifiers Л5-4 and Л5-6 (6Ж4). Each video amplifier is loaded by its own deflection plate (tube Л5-9).

The video amplifiers employ identical circuits and are actually normal wide-band amplifiers with RF correction (inductance coils L5-3 and L5-4).

For alternate connection of the video amplifiers use is made of voltage Ф c.p.s. synphased with the antenna beam rotation during tracking.

This voltage is applied from the reference voltage generator unit Д-1, to the primary winding of balancing transformer Tp5-2 through connector ШВ5-1, contact 9. From the secondary winding the anti-phase voltages (about 130 V) are impressed on the grids of the switching stage (valve Л5-5, type 6Н9С). The switching stage is a two-way clipping amplifier, whose cathode is fed with -255 V. On the anodes of clipping amplifier Л5-5 anti-phase half-cycle pulses are squared (See Fig.52). Since the loads of the clipping amplifier are connected between the anodes of valve Л5-5 and "earth", the upper level of the square pulses is clamped at all times at the "earth" potential when the triode is cut off, and the lower level of the pulses is -160 V when the triode is conducting (in the selected operating condition). The anodes of triodes Л5-5 are coupled to the suppressor grids of video amplifiers Л5-4 and Л5-6. With the suppressor grid at -160 V in the selected operating condition, valve 6Ж4 is cut off reliably. Consequently, during operation of the switching stage the video amplifiers are driven into conduction and are cut off alternately every half-period of the Ф-cycle voltage developed by the reference voltage generator. Therefore, the video signals are passed to plates $Д_1$ and $Д_2$ of tube Л5-9 alternately, too. The simplified circuit of the switchable video amplifier is shown in Fig.52.

To obtain a clear picture of the target when taking its bearings, it is necessary that the number of target echoes passed to the plates of the tracking indicator should be equal to 6 - 8, which corresponds to a 40° turn of the radiator during conical scanning at the Ф-cycle frequency.

The video pulses are furnished to plates $Д_1$ and $Д_2$ of the tracking indicator tube alternately during every half-cycle (180°) of the antenna beam rotation. But since only 40°

of the antenna beam rotation are should be used for obtaining a clear picture and accurate bearings of a target, use is made of 40° brightening. When the target is swept by the equisignal zone, the video pulses appear on the indicator screen only during the period the antenna beam covers about 40° in the left and right azimuth positions of the antenna beam in case of conical scanning. The 40° brightening is obtained by means of the brightening channel in the tracking video amplifier. In this channel are squared the pulses brightening the pattern on the tracking indicator tube at the moments when the antenna beam passes an angle of 40° in the left and right azimuth position of the beam (Fig. [illegible]).

The first shaping stage - Valve Л5-10, type [illegible]. The valve grids are fed with anti-phase sinusoidal voltages from the secondary winding of transformer Tp5-2. As the time constant of transmission circuit C5-27, R5-30, R5-101 and C5-28, R5-[illegible] R5-102 is rather small (1.0 μF, 20 megohms), and the voltage value is large (about 130 V [illegible]), the sinusoidal voltages of [illegible] c.p.s. are limited unilaterally in either triode. The parameters of this circuit ensure that the anode current of the valve [illegible] for about 4 microsec. during the [illegible] half-wave of the [illegible], since [illegible] c.p.s. corresponds to approximately a period of 34 microsec. or to the turn of the antenna beam through 360°. 40° of the antenna beam rotation corresponds to about 4 microsec.

The [illegible] double frequency [illegible] c.p.s.) [illegible] from load R5-29 of valve Л5-10 and [illegible] to the second shaping stage (half of valve Л5-8, type 6Н8С). In this [illegible] the rounded pulse peaks are clipped by the [illegible], which results in positive square pulses [illegible] on the anode of half of the valve. The voltage waveforms are shown in Fig.53.

Further the positive-going 40° brightening pulse is supplied to mixer Л5-[illegible] (valve 6Н8С) where it is mixed with the range mark. The [illegible] a positive pulse [illegible]

1.5-microsec. duration, which is produced in range unit Л-7. This pulse is closely timed with the pulse triggering the range sweep of the tracking indicator, i.e. it always follows the sweep trigger pulse after each 34 microsec. Therefore, the range mark must always be in the middle of the sweep trace.

In order to obtain a sharp, focused bright range mark, the range mark pulses are applied to the cathode-ray tube in intervals between 40° brightening pulses. This happens as follows: both triodes of valve Л5-11 where the signals are mixed, have common cathode resistor R5-39 shunted by capacitor C5-32. The capacitor resistance is high for the 4-microsec. pulse and low for the 1.5-microsec. pulse. When the positive 40° pulse arrives at the grid of the left triode of the mixer, the other mixer grid proves to be cut off due to the 40° pulse being repeated on cathode resistor R5-39 in magnitude sufficient for cutting off the adjacent triode. In the absence of the 40° pulse the right triode operates as an amplifier. From the common anode load the mixed pulses are communicated to the cathode of the cathode-ray tube and modulate the latter in intensity.

The mixer [illegible] and voltage waveforms are shown in Fig.54.

[illegible] switch on the control panel in position SEARCH ([illegible]) and MANUAL I (РУЧН.I), relay P5-1 is dead, and only [illegible] stage (Л5-4) is functioning. In this [illegible] screen presents the pulses at the right [illegible]

[illegible] on the control panel is set at MANUAL II and [illegible] ([illegible]), the relay is fed with +27 V. The second [illegible] starts functioning, and the screen [illegible] moving both sides. The switching stage begins [illegible] simultaneously.

[illegible] supply circuit and reduce the number of [illegible] blocking capacitors, the minus of the high voltage [illegible] to the cathode of tube Л5-9, while the plus is earthed. The high-voltage from the -1500-V rectifier is impressed to the high-voltage divider which feeds all the electrodes of cathode-ray tube Л5-9. The brightness is controlled by potentiometer R5-57. The horizontal and vertical displacement is carried out by the symmetrical voltage taken from ganged potentiometers R5-48, R5-49, R5-54, R5-35, connected between the +300-V and -255-V stabilized supplies.

Sighting indicator channel

The sighting indicator channel comprises:

(a) cathode-ray tube Л5-14, type 8Л029;

(b) clipping amplifier and saw-toothed voltage phase-inverter amplifier(valve Л5-12);

(c) video amplifier valve Л5-13, type 6Ж4.

The cathode-ray tube presents A-display (See Fig.55).

The sweep voltage is the voltage applied from the sweep unit to the deflection coil of the search indicator. The saw-toothed voltage is clipped and amplified by valve Л5-12 (6H8C). The operating condition of this valve ensures rather a good clipping of the saw-toothed wave pedestal and amplification of the saw-toothed voltage at the output. This results in appearance on the sighting indicator of sweep durations corresponding to the search indicator sweeps 100 and 200. Fig.55 shows that the saw-toothed voltage amplitude produces a sweep larger in size than the working part of the screen. The working part of the screen is 55 to 60 mm and in case of range 100 it should contain a working range of about 80 ± 4 km. with 15 per cent linearity.

The grid of the clipping amplifier (valve Л5-12,type 6H8C) is fed with saw-toothed voltage (with pedestal) from the search channel (contact 14 of connector ШВ5-8). A saw-toothed voltage pulse at the output of valve Л5-12 (contact 2) is 170 V. This pulse is applied to one of the horizontal plates (contact 7 of the cathode-ray tube); simultaneously part of this voltage taken from the divider (variable resistor R5-85) is applied to valve Л5-12, where it is turned over and amplified. The turned-over saw-toothed voltage equal to 170 V is applied to the horizontal plate (contact 8) of the tube from the output of the phase-inverter amplifier.

The required linearity is ensured by optimal current negative feedback (resistors R5-84 and R5-86) in both valves.

The sighting sweep trace is brightened by the brightening pulse of the search indicator. This square-wave voltage is taken from part of the anode load of valve Л5-1 (resistor R5-17) and applied to the grid of cathode-ray tube Л5-14 (contact 3).

The signals coming from the sweep unit mixer are amplified by valve Л5-13 (6Ж4); the linear characteristic is obtained by introduction of current negative feedback (R5-84). The sighting indicator can also be used for viewing the processes occurring in various circuits of the radar. For this purpose, the sweep can be started by an external pulse (See sweep unit Д-4М) and the indicator functions as a synchroscope.

This is achieved by setting switch OPERATION-CHECK (РАБОТА-КОНТРОЛЬ) to position CHECK and feed an external pulse to start the sweep to test jack 3 (Г4-3) located on the front panel of the sweep unit.

Tube Л5-14 is supplied in essentially the same way as tube Л5-9 from a common rectifier (-1500 V).

Brightness is controlled by potentiometer R9-63 and focus, by potentiometer R5-66. The horizontal and vertical centering is symmetrical and effected by gang potentiometers R5-71, R5-72, R5-94, R5-95, connected between the stabilized power supplies (+300 V and -255 V).

Unit supply

The filaments of all the electronic devices are supplied by filament transformer Тр5-1 connected to 115 V, 400 c.p.s. mains. The secondary windings are distributed as follows:

(a) winding II feeds the filaments of valves Л5-1, Л5-3, Л5-4, Л5-5, Л5-6, Л5-8, Л5-10, Л5-11, Л5-12 (6.3 V, 6 A);

(b) winding III feeds the filament of tube Л5-2 (6.3 V, 0.6 A);

(c) winding IV feeds the filaments of tubes Л5-9 and Л5-14 (6.3 V, 0.5 A);

(d) winding V feeds lighting lamps СМ-36 - Л5-16, Л5-19, Л5-20, Л5-21 (3 V, 0.8 A).

The anode circuits of the tracking indicator valves are fed with unstabilized voltage of +300 V (about 25 mA), and anode circuit of the search and sighting indicators, brightness control circuit of the search indicator and beam-shift control circuits of the tracking and sighting indicators are supplied with the regulated voltage of +300 V (about 30 mA) applied to unit Д-5 from supply unit Д-8. When supplied with -255 V reg., unit Д-5 consumes a current of some 14 mA.

The 1500-V rectifier is supplied from 115 V, 400 c.p.s. mains. The total consumption by unit Д-5 when fed with 115 V, 400 c.p.s. is not more than 1.4 A.

6. Remote Indicator Д-6М

Purpose

The remote indicator (PPR) in radar K-IIM is intended for:

(a) determining the range of a target or a group of targets;

(b) determining the azimuth of a target or a group of targets;

(c) determining the aircraft heading.

The indicator presents a plan of the positions of all targets within a circular area. The echo pulse voltage is applied to the control grid of the cathode-ray tube, which causes increase in intensity of the electron beam during the working time of the pulse.

Basic circuit of unit П-6М

The basic circuit of the PPR (Fig.81) consists of a cathode-ray tube, type 13ЛМ31, with its equipment, brightening pulse shaping stage and video amplifier Л6-1, type 6Н1П.

The cathode-ray tube equipment comprises:

(a) rotary deflection coil L6-2;

(b) selsyn-motor М6-1, type СМС-1, rotating deflection coil L6-2;

(c) focusing permanent magnet with adjustable shunt;

(d) centering system for shifting the electron beam on the screen of cathode-ray tube 13ЛМ31 in horizontal and vertical directions.

(e) phasing contacts for synchronizing the rotation of the deflection coil with that of the radar antenna.

The deflecting saw-toothed current is delivered to deflection coil L6-2 from the sweep unit. The deflection coil is rotated in step with the antenna around the neck of the cathode-ray tube. The deflection coil is rotated through gearing 10:1 by receiving selsyn М6-1 (type СМС-1).

The phasing switch is intended for connecting the receiving selsyn to the transmitting selsyn (antenna-mounted unit Д1) in one of its ten positions. The switch contact may be shorted by means of relay Р12М-1.

Fig.57 shows the schematic diagram of the receiving selsyn, type СМС-1.

The signal of the video amplifier of the sweep unit is communicated to the plan position repeater through coaxial cable 4[illegible] and box [illegible]. This signal is passed over cable 35 to the cathode of the second triode of valve Л6-1 (6Н1П). This is a compensated video amplifier of unipolar signals. The width of the amplifier passband is about 0.1 to 1.8 Mc/s. From the output of the video amplifier a positive signal is furnished to the grid of cathode-ray tube Л6-2 (13ЛМ31). The cathode of the first triode of valve Л6-1 is fed with a sweep trace brightening pulse from the sweep unit (over a multi-core screened cable).

The brightening pulse is passed to the first anode of tube Л6-2 from the anode of first triode of valve Л6-1. The video amplifier is necessary because of substantial losses in the long video cable and for ensuring the frequency passband.

The indicator beam brightness is controlled by varying the positive potential at the cathode with potentiometer R6-8 BRIGHTNESS (ЯРКОСТЬ).

Focusing and centering are effected by means of a permanent ring-shaped magnet.

The ring-shaped magnet is assembled in a magnetic system with controls brought out.

The beam centering is achieved by moving the magnetic shunt while rotating knobs VERTICAL CENTERING (ВЕРТИКАЛЬНАЯ ЦЕНТРОВКА) and HORIZONTAL CENTERING (ГОРИЗОНТАЛЬНАЯ ЦЕНТРОВКА).

Focusing is controlled by knob FOCUSING (ФОКУСИРОВКА) coupled with the magnetic shunt moving on the helical rails of the magnetic assembly along the magnet axis, thus changing the field.

+4900 V D.C. is supplied to the second anode of the tube from high-voltage rectifier Д-25.

A D.C. regulated voltage of +300 V, feeding valve Л6-1, the first anode and brightness control divider of tube Л6-2, is delivered from regulated rectifier Д-8.

The filament voltage to valve Л6-1 (6Н1П), tube Л6-2 (13ЛМ31) equal to 6.3 V and to dial lamps ЛН6-3, ЛН6-4, ЛН6-5 equal to 3 V is applied from the step-down transformer of unit Д-22.

The rotor of selsyn-motor M6-1 operates on 115 V, 400 c.p.s. from the inverter.

The brilliance of the dial lamps is controlled by means of rheostat R6-11.

Unit supply

The unit is supplied from the following sources:

(a) 115 V ± 3 V, 400 c.p.s.+40,-20 c.p.s.;

(b) regulated voltage +300 V ± 3 V;

(c) D.C. voltage +4900 V ± 300 V.

7. Autoselector Д-7

Purpose

The purpose of autoselector unit Д-7 is to synchronize the radar operation, follow the target automatically in range and select the target video pulses for the elevation tracking unit and AGC channel.

Composition of unit

Autoselector Д-7 consists of two main parts which are a selector and a lock unit.

The lock unit is mounted on the first subpanel and consists of the following assemblies:

(a) Crystal oscillator designed for stabilizing the mid repetition frequency of the pulses generated by the unit.

(b) Voltage dividers converting high frequency of the crystal (60 Kc/s) to a series of short pulses with repetition frequency n_1 or n_2 c.p.s.

(c) Frequency modulation phantastron modulating the repetition frequency of the synchronizing pulses.

(d) Output cathode followers allowing the output synchronizing pulses of the unit to be passed through long screened conductors.

(e) 90-microsec. delay multivibrator designed for displacing the transmitter trigger pulse for a time equal to the initial delay of the range mark in the selector circuits (fixed delay of 90 microsec. is connected when the radar is operated on CHECK).

(f) Delay line producing a small additional delay (about 1 msec.) of the transmitter trigger pulses.

The selector portion of the unit is mounted on the second and third subpanels and consists of the following assemblies:

(a) Comparator comparing the time delay of the tracked target signal with the delay of the gate pulses produced by the unit. If the delays are not coincident, the comparator produces the respective error voltage.

(b) Double integrator converting the pulse error voltage to constant control voltage for the range phantastron. It also ensures the velocity memory of the system.

(c) Variable delay (range) phantastron delaying the gate pulses. Together with the integrator and comparator it forms a servo system for automatic target tracking.

(d) Selector proper designed for separation of the target tracking pulse from all the targets within the swept area.

Description of functional diagram

Fig.58 is a representation of the autoselector.

The crystal oscillator produces a stable frequency of 60 Kc/s.

The frequency dividers reduce the crystal frequency in three stages (3:1, 4:1 and 4:1).

The third frequency divider generates pulses at frequency n_2 c.p.s. and starts the modulation phantastron. The trailing edge of the phantastron pulse controls the moment all synchronizing pulses of the unit are generated.

The control circuit of the phantastron is fed with sinusoidal voltage from the reference voltage generator.

The phantastron pulse length being changed, all the synchronizing pulses produced by the unit are proved to be frequency-modulated.

The check pulse of circuit K-I is the first in time to go (time moment t_1, Fig.9, Part I).

The suppressor and sweep trigger pulses are delayed by 90 microsec. with respect to the above-mentioned pulse. The transmitter trigger pulse is delayed in addition by 1 microsec. with respect to the suppressor and sweep trigger pulses.

The synchronizing pulses are communicated to the external circuits through the cathode followers.

The variable delay phantastron circuit is started at time moment t_1.

The trailing edge of the phantastron pulse controls the moment the tracking indicator trigger pulse is generated, and the moment of operation of the fixed delay multivibrator (34 microsec.).

Position of the multivibrator pulse trailing edge assesses the moment of operation of the blocking oscillator which, in turn, triggers the 1st and 2nd gate pulse oscillator, the 2nd pulse being delayed by the delay line by 0.7 microsec. with relation to the 1st pulse. The range mark formed in the circuit is delayed by 0.35 microsec. with respect to the 1st gate pulse.

The tracking indicator trigger pulses, gate pulses and range mark can be simultaneously displaced with respect to moment t_1, provided mutual time delays between them are retained.

Since generation of the enumerated pulses is associated with functioning of the variable delay phantastron, variation of the phantastron pulse duration allows the pulses to be displaced with the entire distance range, and gate pulses can be matched with it upon arrival of the target pulse.

Through the comparator and integrator circuits the target pulse controls the duration of the variable delay phantastron pulse keeping the gate pulses automatically in the stage of balance with regard to itself (the so-called target tracking).

The pulse of the tracked target and the selecting pulse are applied to the coincidence stage.

The coincidence stage allows the tracked target pulse to pass through the selector channel, preventing the passage of all pulses from the other targets. The pulse selected is amplified and through the cathode followers is furnished to the external circuits (to units Д-3, Д-4М and Д-10).

Description of schematic diagram of unit

(Fig.59)

(a) Lock unit

Crystal oscillator and pulse generator

The crystal oscillator (Fig.60) employs valve 6H8C (Л7-1); the crystal is connected between the grid and cathode of the valve.

To obtain generation the circuit in the anode is tuned to a frequency higher than that of the crystal plate (f crystal-60 Kc/s).

During functioning of the crystal oscillator, the grid of valve Л7-1 is kept at a great negative bias due to which the anode current flows not continuously, but pulsewise.

The anode current pulses are passed through transformer Tp7-1 winding and develop a voltage across it (See Fig.61) synchronizing the blocking oscillator (utilizes the right portion of valve Л7-1).

Functioning of the blocking oscillator is illustrated in Fig.62. When the anode current passes through the transformer, a positive voltage is induced on the grid causing the anode current to rise.

The grid current flowing through resistor R creates a voltage of the opposite polarity and charges capacitor C.

When the anode current stops rising, the grid voltage is not induced. The valve is driven sharply to cut-off by the negative voltage across the capacitor, and the latter starts discharging through resistor R. Damped oscillations are excited in the anode, and pointed peaky pulses are produced at the output (point A).

The pulse generator of unit Л-7 functions in essentially the same way.

With the positive voltage at the grid of the right portion of valve Л7-1, capacitor C7-104 acquires a charge. The capacitor discharges through resistor R7-106.

The output negative pulses having a frequency of 60 c.p.s. are taken from resistor R7-104.

Frequency dividers

The synchronizing pulses taken from resistor R7-104 are furnished to the cathode of the left portion of valve Л7-2.

This stage (Fig.63), which is actually a blocking oscillator, is intended for dividing frequency (1st frequency divider).

The functioning of the blocking oscillator is analogous to that of the pulse generator, the difference being that the time constant of the circuit (C7-108, R7-107, R7-108) is approximat three times as large as the time constant of the pulse generator circuit.

Owing to this the blocking oscillator is triggered only by the fourth pulse furnished by the pulse generator, since certain synchronizing pulses (2nd and 3rd in Fig.64) fail to open the valve during the charge reduction time of the capacitor.

Thus, the circuit acts as a frequency divider (3:1). Potentiometer R7-107 is used for varying the circuit time constant, which is necessary for obtaining stable division.

The output negative pulses are taken from resistor R7-110 and furnished to cathode 2 of the frequency divider (right portion of valve Л7-2) whose division ratio is 4:1.

Potentiometer R7-115 is used for varying the time constant of the circuit (C7-114, R7-116, R7-115).

Taken from resistor R7-113 are negative pulses going to cathode 3 of the frequency divider (left portion of valve Л7-3) whose division ratio is 4:1.

The time constant of the circuit (C7-116, R7-118, R7-117) is adjusted by potentiometer R7-117. The output pulses of frequency n_2 pulses per second are taken from resistor R7-120 (negative) and from divider R7-123, R7-124 (positive).

The stability of the obtained pulse sequency is rather high, for the frequency is crystal-controlled.

Modulation phantastron

The negative pulses from the 3rd frequency divider are passed to the phantastron circuit.

The phantastron is a modification of the cathode-coupled multivibrator which employs a multigrid valve - pentagrid 6A7 instead of two valves.

The simplified circuit of the phantastron is shown in Fig.65, and characteristic curves in Fig.66.

Valve 6A7 can be considered as a pentode whose screen grid is substituted by the whole system formed by three grids G_2, G_3, G_4.

The second and fourth grids are coupled together; they are fed with a positive voltage and function as a screen grid. The voltage on grid G_3 may be higher or lower than that on the cathode; this grid functions as an additional control grid.

Due to provision of the screen grid the variation of the voltage being applied to grid G_3 has no noticeable effect on the total amount of the cathode current of the valve which is essentially the sum of the anode current and current of the screen grid; however, the magnitude of this voltage governs the current distribution between the anode and the screen grid.

If the voltage at grid G_3 has a large negative magnitude with respect to cathode, the electrons leaving the cathode are not able to pass the grid; for this reason all the electrons are directed to the screen, and the anode current is blocked. The voltage rise on grid G_3 causes an increase in the anode current and a corresponding decrease in the screen grid current.

In grid G_3 itself the current appears when its voltage reaches the cathode voltage. Like the control grid of a pentode, grid G_1 controls the total of the anode current and the screen grid current. Grid G_5 functions normally as a suppressor grid.

Voltage to screen grid G_2-G_4 is picked off voltage divider R7-132, R7-133 (134).

The current in the cathode circuit of valve Л7-4 is to a great extent determined by the screen current.

A voltage drop of about +40 V occurs across resistor R7-130. A voltage divider formed by resistors R7-128, R7-129 feeds grid G_3 with a bias of about +25 V with respect to earth. Thus the bias set up on grid G_3 is -15 V with respect to cathode and its magnitude is large enough to drive the valve to cut-off.

This steady initial state is illustrated in Fig.66 as stage VI.

The stage is characterized by that the anode current is blocked with the potential at grid G_3, and the screen grid current is controlled with the potential at grid G_1. Due to a large value of resistor R7-131 the anode current is maintained at a level pre-set by potentiometer R7-126, through a diode (right portion of valve Л7-3).

The cathode voltage of this diode is actually the control voltage of the phantastron.

Grid G_1 is connected to the +300-V supply through resistor R7-132 and it is kept at zero bias with respect to cathode. Capacitor Cg is charged to the control voltage minus the initial voltage on grid G_1 with respect to earth.

The cathode of diode Л7-3 is furnished with a negative pulse from the 3rd frequency divider. In this case, the cathode potential becomes more negative relative to anode, causing the anode current in the diode to increase. This current while flowing through resistor R7-131 develops a voltage drop across it.

As a result, the anode voltage of the phantastron decreases. The negative pulse is also communicated to grid G_1 via capacitor Cg, which involves reduction of the current flowing through cathode resistor R7-130. The positive potential on the cathode decreases, which lowers the bias on grid G_3 and gives start to the flow of the anode current (Fig.66, stage I).

Capacitor Cg has no time to discharge materially through resistor R7-135. The cathode voltage becomes so low that grid G_3 does not prevent the passage of the anode current. The duration of the above-mentioned stage I is approximately 4 microsecs.

The next stage of phantastron operation is characterized by the voltage dropping on the anode in a linear manner. The negative feedback through capacitor Cg ensures the constant rate of voltage variations.

This gives start to discharge of capacitor Cg charged to the control voltage determined by the position of potentiometer R7-126 slider, minus the inital voltage on grid G_1.

There is no current in the circuit of grid G_1 and its potential starts rising to +300 V. The anode current and the potential of screen grid G_2-G_4 increase. The resultant anode voltage drop is supplied to grid G_1, thereby preventing the rise of its positive voltage.

That is the result of the feedback effect. The voltages on the anode and screen grid drop so that the anode current ceases to increase when the positive voltage rises on the grid.

The time of the linear voltage drop is proportional to the control voltage set by potentiometer R7-126.

In the next cycle (stage III, Fig.66) there is no feedback, the anode voltage rises slightly.

The voltage on control grid G_1 rises tending to reach the plus (+) of high voltage according to the time constant of Cg Rg, the cathode voltage and screen grid current increase, too. Due to a voltage drop on the screen grid, the anode current would have to rise. But the rise of the current flowing through resistor R7-130 causes an increase of the bias on grid G_3. This prevents increase of the anode current, and the anode voltage rises continuously.

At last the cathode voltage so rises that the anode current is clipped by the bias on grid G_3. This process lasts about 1.5 microsecs.

When the anode current is clipped and the voltage on the screen grid drops, the blocking oscillator gets excited. The blocking oscillator uses valve Л7-5 (right portion of the valve)

The voltage rise on grid G_1 is backed by the rise of the anode voltage. The screen grid voltage drops rapidly due to the increase in the grid current.

The rate at which the anode voltage rises is determined by the rate of fall of the anode current depending on the bias at G_3 and RC time constant (Fig.66).

The voltage on the screen grid drops to such a degree at which its current ceases to grow as the bias on grid G_1 decreases.

Before the phantastron comes back to the initial stage discussed above, the following phenomena take place in it.

The anode voltage rises as high as the control voltage. Capacitor Cg charges to the same voltage magnitude. The anode voltage rises with the RC time constant tending to reach the plus of high voltage. As the anode voltage rises, the voltage across capacitor Cg rises too. The anode voltage rises until it is clipped by the diode. It remains constant before arrival of the next trigger pulse.

The considered process results in the moment of operation of the blocking oscillator, utilizing the right portion of valve Л7-5, being time-delayed with respect to the trigger pulse arriving from the 3rd divider. The amount of delay depends upon the control voltage.

The moment of operation of the blocking oscillator determines the beginning of the shaping process of all synchronizing pulses produced by the unit.

With the constant magnitude of the phantastron control voltage, the synchronizing pulses are displaced by the amount of delay produced by the phantastron, but their repetition frequency remains equal to the frequency of the pulses of the 3rd divider, i.e. n_3 pulses per second.

To obtain frequency modulation (wobbulation), alternating sinusoidal voltage of 10 c.p.s. frequency taken from potentiometer R7-007 slider is superimposed on the constant control voltage (10 c.p.s. voltage is applied to the potentiometer from the reference voltage generator or from the RC oscillator of the course indication unit).

When acted on by the control voltage varying sinusoidally the delay produced by the phantastron varies sinusoidally, too, due to which the interval between the adjacent pulses increases or decreases.

This variation of the interval is tantamount to frequency modulation in the course of which frequency n_2 receives increment $\Delta n_2 \sin(2\pi 10 t)$.

The ratio of maximum frequency increment Δn_2 to initial frequency n_2 is called the relative frequency deviation (ε). Using potentiometer R7-007 located on the front panel of the unit allows any frequency deviation to be set within 0 to 1 per cent.

In the course of frequency modulation, during the time the modulating voltage changes from zero to maximum (i.e., for the half-cycle of the modulating voltage), every following pulse is displaced with respect to the preceding one. The total time displacement t_m of the pulse in relation to its position is determined, in the absence of modulation, by expression

$$t_m = \frac{\varepsilon}{2\pi f_1}$$

The displacement of pulses is the result of variation of the delay produced by the phantastron, owing to which the linear section of the phantastron (unit Д7) exceeds two t_m microsec., and the initial control voltage of the phantastron provides for operation on the linear portion of the characteristic curve (Fig.67).

Frequency divider 2:1

In the search mode relay P7-1 is caused to operate (See the schematic diagram).

The relay operates when the radar is on and switch RANGE, KM. (ДАЛЬНОСТЬ В КМ) is set at 200 km. In this case, the phantastron and difference amplifier utilizing the left portion of valve Л7-5 are disconnected.

The synchronizing pulses from the 3rd divider picked off resistor R7-123 are furnished through capacitor C7-118 and the relay contacts to the control grid of the blocking oscillator; the time constant of the blocking oscillator time-setting circuit increases, for resistor R7-137 (750 kilohms) is connected in place of gridleak R7-136 (30 kilohms).

In this condition the blocking oscillator functions as a frequency divider 2:1. Hence the frequency of all the synchronizing pulses produced by the unit equals n_1 pulses per second.

Output cathode follower of test circuit K-1

The positive pulse is fed from the 3rd winding of the pulse transformer to the grid of the cathode follower (left portion of valve Л7-6, type 6H8C) through coupling capacitor C7-129 (See Fig.68).

From resistor R7-146, connected into the cathode of valve Л7-6 is taken K-1 test pulse (moment t_1 of time-relationship diagram, Fig.9).

The pulse is supplied to the external circuit via prong 1 of the connector.

To reduce the quiescent current the valve cathode contains a self-bias circuit consisting of resistor R7-147 shunted by capacitor C7-131 (the circuit contains several cathode followers connected similarly).

90-microsec fixed delay multivibrator

To compensate for initial delays in the selector which total to about 90 microsecs, some lock unit pulses (the suppressor and sweep trigger pulse, transmitter trigger pulse) are delayed by 90 microsecs, too.

The delay is effected by the multivibrator (Fig.69).

The multivibrator employs valve Л7-7 and is actually a normal cathode-coupled multivibrator.

The left portion of the valve is normally cut off by a large negative bias formed by the voltage drop across common cathode resistor R7-152 when it carries the current of the right portion of valve Л7-7.

The multivibrator is triggered through a buffer amplifier (right portion of valve Л7-6). The amplifier grid is fed with a trigger pulse (moment t_1, Fig.69). Across the anode resistor common for the left portion of valve Л7-7 and the right portion of valve Л7-6 is developed a negative pulse, that passes to the grid of the right portion of valve Л7-7 through capacitor C7-138. The current stops flowing through the right portion of the multivibrator, and now the left portion is under current (turn-over process).

Such a condition lasts until capacitor C7-138 is charged through resistors R7-156, 157 to a magnitude sufficient for driving the right portion of the multivibrator valve into conduction.

The circuit returns to the initial state.

Across the anode load of the multivibrator are squared the pulses whose duration may be adjusted by means of resistor R7-156.

The positive square pulse of 90 microsecs is furnished from the anode of the right portion of the multivibrator valve to winding I of pulse transformer Тр7-6, connected into the anode of the biased blocking oscillator using the left portion of valve Л7-8.

As a result of the existent differentiation, two pulses are formed across the pulse transformer winding: positive, corresponding to the leading edge of the pulse, and negative, corresponding to its trailing edge (Fig.70). The pulses are of the reversed polarity across the winding connected into the grid circuit.

The first, i.e. negative pulse has no effect on the cut off valve, the second - positive pulse makes it conducting thereby causing operation of the blocking oscillator.

The moment of operation of the blocking oscillator appears to be delayed by 90 microsecs relative to the trigger of the multivibrator.

When relay P7-3 is deenergized, the multivibrator is isolated from the circuit and the blocking oscillator is caused to operate by the multivibrator trigger pulse.

The positive pulse from the 3rd winding of pulse transformer Tp7-6 via capacitor C7-149 is applied to the grid of the cathode follower (the left portion of valve Л7-9). The suppressor and sweep positive trigger pulse are taken from the cathode load. The pulse is furnished to the external circuits through prong 3 in the connector.

Besides, the suppressor and sweep trigger pulse is coupled to delay line Z7-1.

To eliminate reflection of the pulse from the end of the delay line, matching resistor R7-169 is connected to the exit of the line. The delayed pulse is passed to the grid of the cathode follower (right portion of valve Л7-9).

The trigger pulse of the transmitter-receiver unit is taken from cathode load R7-168.

The pulse is passed to the external circuit through prong 8 of the connector.

Due to provision of the delay line the trigger pulse of the transmitter-receiver unit is 1 microsec. late relative to the suppressor and sweep trigger pulse.

Delay line

Delay line Z7-1 consists of three sections. Each section is actually a single-layer coil wound on a pertinax bar. The coil inductance is 220 µH. The coil is enclosed in an earthed screened cylinder. The coil capacity with respect to the screen (C=550 pF) is distributed evenly over the entire length of the coil.

One section of the line delays the signal by the time equal to $\tau_3 = \sqrt{L \cdot C} = 0.35$ microsec.

The delay line consists of three sections, consequently, the total delay of the pulse is 1.05 microsecs. The delay line loaded by resistance R equal to its characteristic impedance, i.e., $R = \rho = \sqrt{\frac{L}{C}} = \div 620$ ohms.

Note: Delay line Z7-3 used in the unit is composed of two sections τ = 0.7 microsec.), and Z7-2 of one section (τ=0.35 microsec.).

(b) Selector

At time moment t_1 (See Time Relationships, Fig.9) the variable-delay(range phantastron is triggered.

The duration of the phantastron pulse can be varied by means of external controls or, in case of automatic tracking, by the target pulse.

Position of the trailing edge of the phantastron pulse determines the delay of the selector pulses. These pulses may be displaced over the entire range band, their mutual delays being invariable.

Range phantastron.

The negative trigger pulse is taken from resistor R7-142 and furnished to the cathode circuit of the phantastron diode (right portion of valve Л7-24, type 6H9C).

The control voltage is applied from the circuits of the 2nd integrator (See below).

The variable-delay phantastron (Fig.70) utilizes pentagrid 6A7 (Л7-25). The phantastron circuit contains two additional valves.

One of them (left portion of valve Л7-24) is a cathode follower which serves to reduce the restoration time of the phantastron anode voltage. This is necessary because the linear portion of the anode voltage drop must make up about 90 per cent of the interval between the trigger pulses, whereas in the circuit devoid of the additional valve the linear portion makes up at best 60 per cent of the interval (See Fig.71).

The other additional valve of the phantastron (left portion of valve Л7-23) clamps the initial voltage on the 1st grid of the phantastron, owing to which stabilization of the phantastron pulse duration is achieved at fluctuations of the feeding voltages.

The pulse from the screen grid of pentagrid 6A7 is differentiated by circuit C7-314 and R7-323 and amplified by the right portion of valve Л7-23 (6H9C). The amplified positive pulse corresponding to the trailing edge of the phantastron pulse (See Fig.72) triggers the blocking oscillator utilizing the left portion of valve Л7-22 (6H8C).

Blocking oscillator

The right portion of valve Л7-22 (6H8C) is a trigger amplifier (See the schematic diagram). The blocking oscillator is triggered on account of the anode load common for the amplifier and blocking oscillator valve which is the winding of pulse transformer Tp7-8. From the third winding of blocking oscillator pulse transformer Tp7-8 the positive pulse is passed to the grid of the cathode follower employing the left portion of valve Л7-20 (6H8C). The positive trigger pulse of the tracking indicator is taken from resistor R7-302 of the cathode follower.

This pulse is furnished to the external circuit through prong 12 of the connector.

Multivibrator

The blocking oscillator pulse taken from resistor R7-316 connected into the cathode of the blocking oscillator starts the multivibrator (See the schematic diagram).

The duration of the multivibrator pulse is set by potentiometer R7-309 and equals 34 microsecs.

Blocking Oscillator

The blocking oscillator employing the right portion of valve Л7-13 (See the schematic diagram) is triggered by the trailing edge of the multivibrator pulse.

The moment the blocking oscillator is caused to operate is delayed by 34 microsecs with respect to the trigger pulse of the multivibrator.

From winding III of transformer Tp7-10 the pulse of 1.2-microsec. duration is passed to the strobe pulse shaping circuits (See below 'Selection of Target Pulse').

Gate pulse generator

The positive pulse from resistor R7-273 is coupled to winding I of pulse transformer Tp7-7 (See Fig.73) through capacitor C7-304.

This pulse starts the biased blocking oscillator using the right portion of valve Л7-20.

Connected into the blocking oscillator cathode are delay lines Z7-2 and Z7-3 loaded by matching resistors R7-272, R7-223. From the input and output of the delay line (Z7-3) are taken 1st and 2nd gate pulses respective and communicated to the comparator circuit.

From the output of delay line Z7-2 the pulse is furnished to the grid of the first portion of valve Л7-12 to shape the range marker.

Comparator

The comparator circuit comprises two coincidence valves (Fig.74).

The coincidence valves are represented by pentagrids 6A7 (valves Л7-14 and Л7-15).

The control grid of valve Л7-15 is fed with the 1st gate pulse, and the control grid of valve Л7-14, with the 2nd gate pulse, the latter being delayed by 0.7 microsec. with respect to the 1st pulse.

The heterodyne grids of these valves coupled together are supplied with video pulses of the circuits from the receiver output.

The comparator circuit contains a diode (left portion of valve Л7-16) designed for D.C. restoration of the video pulse and noise after coupling capacitor C7-216.

Valves Л7-14 and Л7-15 are cut-off on both grids and are triggered only when the pulses applied to the control and heterodyne grids coincide.

The amplitude and duration of the coincidence pulses developed on the anode loads of the pentagrids grow as the degree of coincidence of the pulses arriving at the control and heterodyne grids of the valves increases.

If the 1st gate pulse coincides with the target echo, the current in the circuit of valve Л7-15 is prevalent, and if the 2nd gate pulse, the current in the circuit of valve Л7-14 (See Fig.75). When the gate pulses are in symmetry with the circuit pulse, the current in both valve circuits are equal.

In order to balance the comparator circuit variable resistor R7-001 is connected into the cathode of one of the valves. This resistor is located on the front panel of the unit.

Coincidence pulse amplifier

The coincidence pulses (See Fig.76) are furnished to the single-stage amplifiers (valve Л7-17, 6H9C). The positive pulses from the anode load resistors R7-242 and R7-245 are passed to the 1st integrator circuit.

1st integrator (charge-discharge valve)

The 1st integrator employs two portions of valve Л7-18 (6H9C) each of which is cut off on the grid and opens for a time depending upon the duration of the pulse arriving from the coincidence pulse amplifiers.

The load of valve Л7-18 is a filter formed by C7-224 and R7-251.

As the diagram (Fig.76) shows, opening of the right triode of valve Л7-18 is accompanied by the charge of capacitor C7-224, and opening of the left triode, by the capacitor discharge.

If the grid of the triode is supplied with pulses of equal amplitude and duration, the charge and discharge currents are equal too, and the voltage across the capacitor is kept invariable. This corresponds to the case when the balanced comparator is fed with the receiver noise voltage or a pulse returned from the target whose relative speed is zero.

If the target speed is other than zero, a state of unbalance occurs in the comparator, and depending upon the direction of the target flight the charge or discharge current prevails in the integrator circuit. In this case, a negative or positive voltage proportional to the target speed settles across capacitor C7-224.

By means of the relay contacts additional capacitor C7-225, whose function will be explained below, may be connected to the filter via resistor R7-252.

Cathode follower

The voltage from the detector filter is applied to the grid of the cathode follower employing the left portion of valve Л7-19 (6H8C).

The cathode load of the valve is formed by three voltage dividers: R7-254, 255, R7-256, 257 and R7-258, 002.

From divider R7-254 and R7-255 connected into the cathode circuit of valve Л7-19 a negative bias is taken to the grid of the right portion of charge-discharge valve Л7-18.

Owing to this connection, the grid potential of valve Л7-18 remains approximately constant with respect to its cathode despite the cathode voltage varying in magnitude and polarity.

The arms of divider R7-256, R7-257 are so chosen that the voltage at the point where the above resistors are connected equals that on the grid of the cathode follower (See "Target search" below).

The third voltage divider is composed of potentiometer R7-002 INTEGRATOR BALANCE (БАЛАНС ИНТЕГРАТОРА)on the front panel of the unit) and resistor R7-258. From the potentiometer slider the voltage repeating the voltage on the filter is applied to the second integrator.

2nd integrator

The 2nd integrator (See Fig.77) employing valve Л7-28 (6Ж8) is actually a voltage negative feedback amplifier.

The feedback voltage is applied from the anode of valve Л7-28 (6Ж8) to its control grid through integrating capacitor C7-317.

When the D.C. control voltage is applied to the integrator input (i.e. to the control grid of valve Л7-28 through R7-347) the voltage on the anode of valve Л7-28 varies linearly.

The steepness of the voltage variation on the anode is proportional to the magnitude of the input voltage. Depending upon the magnitude and polarity of the input voltage the anode voltage may vary toward increase or decrease.

The right portion of valve Л7-27 (6H8C) serves to establish feedback that increases the integrator linearity.

The feedback voltage is applied to the screen grid of the integrator valve (See schematic diagram).

The integrator circuit provides for maximum and minimum limiting of the range voltage by the diodes - the right portion of valve Л7-16 (6X6) for maximum limiting of the anode voltage, the right portion of valve Л7-19 (6H9C) for minimum limiting of the anode voltage, and both portions of valve Л7-26 (6X6) for grid limiting in maximum and minimum (See Fig.78).

Changing the radar from the tracking to search condition causes the relay (P7-1) in unit Д-7 to operate. This changes over resistance of divider R7-237, R7-238, R7-126 and R7-239 setting the cathode voltage of the maximum limiter (the right portion of valve Л7-16).

This causes variation of the upper limit of the distance range in the tracking and search modes. Potentiometer R7-126 (MAXIMUM RANGE/ МАКСИМАЛЬНАЯ ДАЛЬНОСТЬ) is used to continuously control the upper limit of the distance range in the tracking mode.

The voltage on the anode of valve Л7-28 (RANGE VOLTAGE) is repeated by the cathode follower employing the left portion of valve Л7-27 (6Н8С) and via resistor R7-325 it is fed to the cathode of diode Л7-24 through which the phantastron is started, controlling the duration of the phantastron pulse.

As a result, a follow up system is formed.

Automatic target tracking

The follow up system is in the state of equilibrium when the video pulse from the target is in symmetry with the gate pulses. In this case the coincidence pulses in both arms of the coincidence circuit are identical, the charge and discharge currents of the filter are equal; the control voltage being impressed on the 2nd integrator corresponds to zero speed and the range voltage is constant.

Variation of the video pulse delay causes a respective unbalance in the comparator. This results in the output voltage of the integrator and phantastron delay varying in such a manner that the range pulses "follow" the target pulse.

With relay P7-2 (Fig.76) energized, the system possesses "memory" in speed, for when the target signal fades out, the range pulses go on moving in the same direction and at approximately the same speed.

The speed "memory" of the system is ensured by a substantial time constant of the filter and by provision of the 2nd integrator.

When the target signal disappears the total charge and discharge current of the filter through valve Л7-18 equals zero and the voltage across the filter decreases with the time constant of the filter. In the consequence of this action the rate of change of the integrator voltage (range voltage) decreases constantly, too, but with a short-time fading of the signal from the target, the mismatch between the gate pulses and the target echo is slight and tracking is continued upon appearance of the signal returned from the target.

Target search

The target search is carried out by feeding cathode follower Л7-19 with the "search voltage" from the control panel via resistor R7-251 and contacts 1 and 2 of relay P7-2 (Fig.81).

In the search mode capacitor C7-225 is disconnected from the filter by relay P7-2.

This causes an abrupt reduction of the filter time constant, which becomes necessary for locking on the target pulse with the assigned search speed.

To make impossible a sudden change of the voltage across the filter when the relay is changed over, which may result in stopping of tracking, capacitor C7-225 is connected to the input of the control voltage cathode follower. With divider R7-256, R7-257 chosen properly, the voltage across capacitor C7-225 remains approximately equal to that across capacitor C7-224 at any search speed.

Selection of target for tracking

The target is furnished from unit Д-3 to unit Д-7 by coaxial cable 41 (See schematic diagram).

If there are several targets, the unit allows one to be selected for tracking. For this purpose the unit has provision for blocking the comparator to drop the target which is not to be tracked.

Blocking is effected by changing the parameters of the divider in the cathodes of valves Л7-14 and Л7-15 by opening the contacts through which resistor R7-234 in the tracking mode is earted. (The contacts are the component part of the combination control marked RANGE located in the control panel, Fig.81).

Disconnection of resistor R7-234 is accompanied by a sudden increase of the positive voltage on the cathodes of the comparator valves, the target signal stops controlling the unit and the gate pulses may be matched with any other target.

Selection of target pulse

To make units Д3, Д-4М and Д10 function, it is necessary to select the signal of the tracked target from all the targets, having cancelled the remaining signals.

With this purpose in view unit Д7 is provided with a selector circuit (See Fig.79).

Video pulses from the target are passed to the grid of coincidence valve Л7-12 (½ 6H8C) through divider R7-210 and R7-221.

This valve is driven to cut-off by the positive voltage on account of the current of the open valve Л7-11 passing through common cathode resistor R7-207.

During tracking of the target the cathode of valve Л7-12 is furnished with a strobe pulse opening the valve. This pulse is shaped as follows:

A pulse from the 3rd winding of pulse transformer Tp7-10 of the blocking oscillator employing the right portion of valve Л7-13 (6H8C) is applied to the input of the amplifier (the left triode of valve Л7-13), the pulse being time-coincident with the 1st gate pulse.

From anode load resistor R7-219, a negative pulse is taken to the grid of valve Л7-11.

This pulse is much in excess of the cut off voltage of the valve which results in cutting off the anode current of valve Л7-11;

A square strobe pulse whose duration is approximately 1.2 microsecs is shaped on the valve Л7-12 cathode.

Due to matching of the pulse from the tracked target and strobe pulse valve Л7-12 opens and the selected pulse passes through the selector channel.

The remaining pulses from the targets are not passed by the valve.

After being amplified in the left triode of valve Л7-11 (½6H8C) the selected pulse is passed to cathode follower Л7-10. From the output of the cathode follower the pulse is communicated by coaxial cable 42 to the AGC circuit of the receiver (unit Д3) and by coaxial cable 48 to the angle tracking unit (unit Д10).

Via the cathode follower (the right portion of valve Л7-8) the selected pulse is furnished to prong 4 of the connector and is applied to unit Д-4М via the valve and multicore cable.

The initial operating condition of the coincidence valve is set by means of potentiometer SELECTION LEVEL (УРОВЕНЬ СЕЛЕКТ) (R7-270).

Control SELECTION AMPLIFICATION (УСИЛИТ.СЕЛЕКТ.) (R7-269) allows the amplification factor of the selector to be varied within 1.2 to 1.4.

Range marker shaping

Shaped in the unit is a range marker intended for producing a bright spot on the indicator screen (unit Д5).

The range marker is obtained by means of the 1st gate pulse delayed by 0.35 microsec. The pulse is furnished to the cathode follower (the right portion of valve Л7-12, type 6Н8С).

From the cathode follower output the pulse is taken to the external circuits (to unit Д-4М and Д5) via prong 2 of the connector.

Control of operation of unit Д-7

Operation of unit Д7 is controlled by means of a combination control situated on the control panel. This control which is actually a potentiometer structurally combined with a series of switches allows all operations on target selection to be done (Fig.81).

Shifting the potentiometer slider permits changing of the direction and search rate. The rate of search rises suddenly when pressing the potentiometer knob to the stops, for this closes contacts 7, 8 or 9, 10 shunting the resistor, and the search voltage rises abruptly.

After a target has been locked on the potentiometer is put to the mid position. In this case, contacts 4, 6 close and the "memory" relay is energized. The target is dropped by pushing the potentiometer knob and turning it clockwise or counter-clockwise. This opens contacts 2, 3 and drives the comparator valves to cut-off; the gate pulses stop matching the target pulse; the tracking of the given target ceases.

In one of the positions of the range-scale selector located on the control panel the winding of relay P7-1 is energised, the repetition frequency of the synchronizing pulses changes from n_2 pulses per second to n_1 pulses per second and wobbulation ceases.

Supply of Unit Д7

The filament circuits of the unit are supplied by 115 V, 400 c.p.s. via step-down transformer Tp7-9.

The anode and bias circuits are fed by the rectifiers housed in unit Д8.

The current drawn from the power supplies makes up:

for voltage of 115 V .... 0.8 to 0.95 A
for voltage of +300 V reg. .... 60 to 80 mA
for voltage of +300 V .... 60 to 70 mA
for voltage of -255 V .... 6 to 8 mA
for voltage of +27 V .... 300 mA

8. Regulated Rectifier Д8

Purpose

The regulated rectifier is designed for feeding the anode-screen circuits and the bias circuits of the radar with rectified voltages of the following ratings:

(a) regulated voltage of +300 V at a load current of 180 mA;
(b) voltage of +350 V at a load current of 130 mA;
(c) voltage of +140 V at a load current of 240 mA;
(d) voltage of +300 V at a load current of 450 mA;
(e) regulated voltage of -225 V at a load current of 50 mA.

The schematic diagram of the unit is shown in Fig.83.

Unit design

There are three transformer Tp8-1, Tp8-2, Tp8-3 to feed the anode and filament circuits of the unit, transformer Tp8-1 feeds the anode circuits of rectifiers: +300 V reg, +350 V and 140 V unreg.

Transformer Тр8-2 feeds the anode circuit of the +300-V unregulated rectifier.

Transformer Тр8-3 feeds the anode circuit of the -225-V regulated rectifier, as well as the filament circuits of all the unit valves.

All the transformers are rated for operation on 115 V, 400 c.p.s.

+300-V regulated rectifier

From the secondary winding of transformer Тр8-1 the alternating voltage is supplied to kenotron Л8-1 (5Ц3С). The rectified voltage is supplied to the output via the filter (С8-1, С8-2, Др8-1) and electronic regulator (valves Л8-2, Л8-3, Л8-4). The electronic regulator (Fig.82) consists of valve Л8-2 (6Н5С) - regulating, valve Л8-4 (6Ж4) - control, and voltage regulator Л8-3 (СГ3С), which serves as a source of reference voltage for the cathode of valve Л8-4 and for voltage divider R8-10, R8-11, R8-12 (Fig.82).

Resistors R8-7, R8-8 serve to limit the current through the stabilivolt, as well as to feed the screen grid of valve Л8-4 (R8-7).

Regulator operation. Suppose the regulator output voltage increases due to a voltage rise at the input of the regulator (or decrease of the load current).
Divider R8-10, R8-11, R8-12 is so selected that the voltage applied from it to the control grid of valve Л8-4 is with the rated voltage at the regulator output, somewhat lower than the reference voltage on cathode of Л8-4 taken from voltage regulator Л8-3. This ensures constant negative bias on valve Л8-4. Therefore the grid potential increases relative to the cathode as the output voltage increases. So does the current flowing through valve Л8-4 and resistor R8-6. This results in an increase of the voltage drop across the resistor and, consequently, of the negative bias on the grid of valve Л8-2; the internal resistance of this valve increases. The voltage drop across valve Л8-2 increases in proportion to the output voltage. As a result, the output voltage remains invariable.

If the input voltage of the regulator decreases (or the load current increases), the control grid potential of valve Л8-4 decreases which causes the voltage drop across resistor R8-6 to decrease and control grid potential of Л8-2 to increase. The internal resistance of valve Л8-2 decreases. The voltage drop across the latter decreases and the output voltage rises to the initial valve.

The magnitude of the rectified regulated voltage may be controlled by potentiometer R8-11 (brought out to the front of the unit panel) marked +300 V reg. (регул.+ 300 V) from the slider of which voltage is taken to the control grid of valve Л8-4.

Capacitor C8-4 passes the ripples directly from the regulator output to the control grid of valve Л8-4.

The output of the +300-V regulated rectifier contains capacitor C8-5 designed to ensure reliable operation of the rectifier under pulse load conditions.

-255-V regulated rectifier

The rectifier valve is actually kenotron Л8-11, type 5Ц4М. The A.C. voltage to the kenotron is furnished from the secondary winding of transformer Тр8-3. The rectified voltage is passed through filter C8-12, C8-13, Др8-5 to the regulator input.

The electronic regulator consists of the following valves: Л8-12(6П3С) - regulating, Л8-13(6Ж4) - control, Л8-14(СГ3С) - voltage regulator in the cathode circuit and circuit of divider R8-24, R8-25, R8-26.

The operating principle of the -255-V rectifier is similar to that of the +300-V rectifier. Resistors R8-31, R8-32, R8-33 connected in parallel with valve Л8-12 serve to alleviate the operating conditions of the valve by carrying part of the load current.

Potentiometer R8-25 located on the front of the unit panel and marked -255 V reg. (-255B ст.) is used to control the rectified regulated voltage.

Connected at the output of the -255-V rectifier is relay P8-1. The relay contacts supply 115 V to the primary windings of anode transformers Tp8-1 and Tp8-2, as well as to the primary winding of the high-voltage transformer in unit Д25. Functioning of the relay ensures delivery of all the rectified positive voltages after a negative voltage of -255 V has been applied to the radar. Upon failure of the -255-V channel, all the voltage delivered to the radar from unit Д8 are removed through the action of relay P8-1.

+350-V rectifier

The rectifier employs kenotron 5Ц4М (valve Л8-5). The A.C. voltage is applied to the valve from transformer Tp8-1. The rectified voltage is impressed on the output via filter C8-6, C8-7, Др8-2.

Potentiometer R8-35 is used for adjusting the magnitude of the +350-V output.

+140-V rectifier

The rectifier employs two kenotrons 5Ц3С (valves Л8-6, Л8-7) connected in parallel. Voltage to the anodes of the kenotrons is applied from transformer Tp8-1. The rectified voltage is impressed on the output via filter C8-8, C8-9, Др8-3.

Potentiometer R8-36 serves for adjusting the magnitude of the +140-V output.

+300-V rectifier

The rectifier employs two kenotrons 5Ц3С (valves Л8-9, Л8-10) connected in parallel. Voltage to the anodes of the kenotrons is applied from transformer Tp8-2. The rectified voltage is applied to the output via filter C8-10, C8-11, Др8-4.

Resistor R8-34 serves for more accurate adjustment of the magnitude of the output voltage.

Protective, signalling and check circuits

The unit provides for fuse protection of all the rectified voltage channels.

Channel +300 V reg. Пр8-1, fuse ПК-0.5 A
+300 V Пр8-2 fuse ПК-0.25 A
+140 V Пр8-3 fuse ПК-0.5 A
+300 V Пр8-4 fuse ПК-1 A
-255 V reg. Пр8-5 fuse ПК-0.25 A

The check circuits in the supply voltage circuits (115 V, 400 c.p.s.) and in the rectified voltage channels are provided with neon lamps, type MH-5.

115 V, 400 c.p.s. - lamp НЛ8-1
+300 V reg. lamp НЛ8-2
+350 V lamp НЛ8-3
+140 V lamp НЛ8-4
+300 V lamp НЛ8-5
-255 V lamp НЛ8-6

The unit allows all the voltages to be checked using test jacks Г located on the front panel of the unit.

Voltage 115 V, 400 c.p.s. is measured across jacks Г8-2, Г8-3.

The same voltage being applied to unit Д-25 is measured across jacks Г8-9, Г8-3.

The voltages below are measured:

+300 V reg., across jacks Г8-5 - Г8-1
+350 V reg., across jacks Г8-8 - Г8-1
+140 V reg., across jacks Г8-7 - Г8-1
+300 V reg., across jacks Г8-4 - Г8-1
-255 V reg., across jacks Г8-10 - Г8-1

Jack 8-1 is connected to the unit chassis.

9. Bank and Sight Stabilization Unit (Д-9)

Purpose

The function of unit Д9 is two-fold:

1. Bank stabilization of the homing antenna (unit Д1).

2. Control of the sighting antenna (unit Д-15М).

The operation of the unit is illustrated in the functional diagram (See Fig.84).

Bank stabilization of homing antenna

During straight and level flight, the error signal being applied to the input of the bank stabilization channel of unit Д-9 is zero.

The error signal is applied from the bridge diagonal (potentiometer sliders) formed by the bank potentiometer of the vertical gyro and check bank potentiometer (unit Д-1). The bridge operates on 40 V, 400 c.p.s.

When the aircraft is banking the body of the bank potentiometer in the vertical gyro is displaced relative to the potentiometer slider in proportion to the bank angle, which results in unbalance of the bridge.

The A.C. unbalance voltage of 400 c.p.s. (error signal) has an amplitude proportional to the angle of bank and a phase varying with the direction of the aircraft bank (when the bank direction changes, the phase is reversed). The unbalance voltage is applied to the input of the bank stabilization channel (unit Д-9). After passing the error signal amplifier with a differentiating circuit, phase detector, D.C. amplifier, it is amplified and converted to D.C. voltage, which is applied to the unit output.

The D.C. output is impressed on the armature of the bank actuating motor (unit Д1). The motor field winding is connected across 27 V. At small values of the error signal, the motor armature is furnished with D.C. voltage pulses, the direct component of the voltage being proportional to the magnitude of the error signal. Thus, the motor speed is proportional to the magnitude of the error signal; at larger values of the error signal 27 V D.C. is applied to the motor armature.

The bank motor, type ДК-11, drives round the antenna tilt journal axle so that the axle may occupy the horizontal position by moving simultaneously the slider of the check bank potentiometer toward decrease of the bridge unbalance voltage. With the journal axle in the horizontal position, the unput of unit Д9 will not be furnished with an error signal. As a result, voltage is not applied to the bank motor armature from the unit output and the motor comes to a standstill.

Synchronous and inphase rotation of sighting (unit Д-15М) and homing (unit Д1) antennas

The input of the sighting channel of unit Д9 is connected to the rotor of a selsyn transformer, type A-3, (unit Д-15М) which is coupled mechanically to the sighting antenna through gear ratio 1:1. The stator of the selsyn transformer is coupled to that of a transmitting selsyn, type A-3, located in the homing antenna.

The rotor of the transmitting selsyn is coupled through gear ratio 1:1 to the azimuth axle of the homing antenna. The rotor is fed with 40 V, 400 c.p.s.

When there is an angular difference between the rotors of the transmitting selsyn and selsyn transformer, a voltage is taken from the selsyn transformer rotor, proportional to the error angle between the selsyn rotors and reversing the phase with the sign of this angle. This voltage, being an error signal, is passed to the input of the sighting channel of unit Д9 in the way similar to the error signal coming to the input of the bank stabilization channel.

From the output of the signal channel the D.C. voltage is applied to the armature of the actuating motor coupled with the sighting antenna through a reduction gear.

The actuating motor turns the sighting antenna, and with it the rotor of the selsyn transformer toward decrease of the error angle thereby matching the position of the homing and the sighting antennas.

Description of basic circuit (Fig.85)

There are two similar channels - sighting and bank stabilization channels - having absolutely identical basic circuits (a slight difference mentioned below).

The assemblies common for both channels are:

Anode-filament transformer Tp9-1, selector switch B9-1, filters composed of induction coils L9-3, L9-4, L9-11 and respective capacitors.

Transformer Tp9-1 is rated for operation from the 115 V, 400 c.p.s. mains. It has four windings: one primary, and three secondary. Two secondary windings produce 350 V to supply the anodes of the phase detectors, i.e. to obtain reference voltage, one secondary winding feeds the filament circuits of all the valve and is used to produce an artificial error signal for tuning and testing circuits of the unit.

The similar component parts of both channels are:

1. Error signal amplifier - the left triode of valve Л9-1 (Л9-3), type 6H9C, with differentiating circuit formed by resistor R9-7 (R9-57) and capacitor C9-4 (C9-54).

2. Phase detector - the right triode of valve Л9-1 (Л9-3), type 6H9C.

3. D.C. amplifier - valves Л9-2 (Л9-4), type 6H8C.

4. Filters - induction coils L9-1, L9-2, L9-5, L9-6, L9-7, L9-8, L9-9, L9-10, L9-12, L9-13 and respective capacitors.

5. Relay amplifier - polarized relay P9-1 (P9-2), power relay P9-3 (P9-5) and P9-4 (P9-6).

6. Pilot lamps ЛН-1, ЛН-2 (ЛН-3, ЛН-4).

The unbracketed names apply to the sighting channel, and the bracketed ones, to the bank stabilization channel.

Unit supply

The unit operates on 115 V, 400 c.p.s.; 27 V D.C. and +300 V D.C.

Operation of sighting channel

Error signal amplifier

The error voltage is applied to the input of the unit - the 10th prong of connector ШВ9-1. Through switch B9-1 set at OPERATION (РАБОТА) and resistor R9-75 the error signal is passed to gain potentiometer R9-81. (If undamped oscillations occur in the closed-circuit system at the zero position, i.e. the system starts swinging, these oscillations can be stopped by cutting out gain potentiometer R9-81). From the potentiometer slider the error signal is fed to the input of the error signal amplifier (grid 1, valve Л9-1).

The error signal amplifier employs the left triode of valve 6Н9С. The anode is supplied with +300 V D.C. The anode load is resistor R9-1, the decoupling filter is formed by capacitor C9-1 and resistor R9-2, the automatic bias resistor is cathode resistor R9-3.

The amplified error signal voltage is applied from anode 2 of valve Л9-1 to grid 4 of the same valve (the input of the phase detector) through a divider formed by capacitor C9-2 and resistor R9-6.

Fig.83 shows the voltage at the output of the error signal amplifier (grid 4 of valve Л9-1 plotted against the error signal applied to the input of the amplifier (grid 1 of valve Л9-1).

The curve tilt (Fig.87) determines the gain factor of the error signal amplifier.

Phase detector

The phase detector employs the right triode of valve Л9-1.

The anode of the phase detector is fed with 300 V, 400 c.p.s. from transformer Tp9-1. The anode load is resistor R9-5, and cathode resistor is resistor R9-4.

A pulsating voltage is obtained across load resistor R9-5 whose magnitude always remains constant in the absence of the error signal. The A.C. component is taken by shunting resistor R9-5 with capacitor C9-8. The D.C. component of the voltage is applied through differentiating circuit R9-7, C9-4 to the input of the D.C. amplifier (grid 1 of valve Л9-2).

At a considerable lag in the regulating device of the follow-up system, part of which is one of the channels (the sighting channel in the case concerned) of unit Д9, undamped oscillations are likely to occur in the system when the sighting antenna is controlled in proportion to the former error, i.e. there exists a lag between the error time and the time efforts are applied to cancel this error. To reduce the lag in the regulating device, a differentiating circuit (R9-7, C9-4) is provided which gives a leading phase displacement to the error voltage within the frequency band at which oscillations may occur.

The voltage taken from resistor R9-5 is negative.

An A.C. voltage of 300 V, 400 c.p.s. applied to the anode of the phase detector may be considered as a reference voltage relative to which an error voltage impressed on the input of the error signal amplifier is in phase or in antiphase. If the error voltage is in phase with the reference voltage, the voltage on grid 4 of valve Л9-1 (phase detector input) will be in antiphase with the reference voltage and magnitude of the negative voltage drop across resistor R9-5 will decrease. As the error voltage increases, the voltage drop across resistor R9-5 decreases respectively. If the error voltage is in antiphase with the reference voltage, the negative voltage drop across resistor R9-5 increases and will rise as the error voltage rises.

Apart from being fed with the negative voltage depending upon the phase and amplitude of the incoming error voltage, the input of the D.C. amplifier (grid 1 of valve Л9-2) is fed with a positive voltage constant in magnitude. This voltage via resistor R9-8 is taken from the slider of potentiometer R9-79 (BALANCE) which together with resistors R9-9 and R9-10 constitute a voltage divider for the +300-V supply. The resultant voltage is positive.

The resultant voltage at the output of the phase detector (input of the D.C. amplifier, grid 1 of valve Л9-2) and its components plotted against the error voltage applied to the input of the error signal amplifier are shown in Fig.88. Fig.89 shows the output voltage of the phase detector plotted against its input voltage. The curve tilt of Fig.89 determines the gain factor of the phase detector.

D.C. amplifier

The D.C. amplifier employs double triode 6H8C (valve Л9-2); the valve has an unbalanced voltage input and a balanced current output. Its anodes are supplied with 300 V D.C. through the control windings of polarized relay P9-1 and resistors R9-18 and R9-19. The relay control windings and the resistors are the anode loads of the D.C. amplifier.

The balanced current output is determined by the voltage at grid 4 of the right triode of the amplifier varying with the incoming signal inversely to the voltage change at grids of the left triode, i.e. a voltage increase at grid 1 corresponds to a voltage decrease at grid 4 and vice versa.

This results from grid 4 being connected via resistor R9-13 to voltage divider R9-12, R9-14 which is coupled to the anode of the left triode.

Opposite changes of voltages at grids 1 and 4 of the D.C. amplifier agree with opposite changes of the anode currents.

In the absence of an error signal the currents flowing through the left and right triodes of the amplifier and hence through the control windings of the polarized relay must be equal. This is achieved by rotating potentiometer R9-79 BALANCE.

Rotation of potentiometer R9-79 while changing the positive component of the voltage on grid 1 equalizes the voltages on grids 1 and 4 before the moment when the currents through both portions of the valve become equal. In this case, the grid potential to cathode is 8 V.

When the error signal is furnished to the channel input, the currents through the left and right triodes will be reversed.

The nature of current reversal versus the voltage at the input of the D.C. amplifier (grid 1) is shown in Fig.90.

The curve tilt (Fig.90) determines the D.C. amplifier transconductance.

Relay amplifier

The relay amplifier is composed of three relays - polarized relay P9-1 (type PП-5) and two power relays P9-3 and P9-4 (type PЛ-5M).

The polarized relay has three windings: two control windings (3, 4 and 5, 6) and one feedback winding (1, 2). The armature relay occupies the neutral position and closes the contacts in the extreme positions upon operation of the relay.

The power relay has one working winding and one switching contact unit.

In the absence of the error signal, the currents through the control windings of the polarized relay are equal (See Fig.90). The magnetic fluxes set up by these windings are equal, too, and oppose each other.

As a consequence, the resultant magnetic flux is zero and the relay armature is in the neutral position.

When the channel input is fed with an error signal small in magnitude that increases the current in winding 6-5 and decreases accordingly the current in winding 3-4, the resultant magnetic flux caused by the current difference in these windings forces the relay to shift the armature from the neutral to an extreme position and close contacts Л and Я. In this case, +27 V is applied to the relay P9-3 winding. Relay P9-4 changes over its contact unit to supply +27 V to the armature of the actuating motor in the sighting antenna. -27V received by the armature from the contacts of relay P9-3 whose armature is released. Power to the motor field winding is supplied in the sighting antenna.

From potentiometer R9-17 connected in parallel with the contact of the power relays feeding the armature of the actuating motor part of the voltage is taken to the feedback winding (1, 2) of the polarized relay.

The magnetic flux set up by the feedback winding opposes the resultant magnetic flux of the control windings (3, 4 and 6, 5) and compensates for it. The relay armature is reset to the neutral position breaking the power supply circuit of relay P9-4 winding.

Relay P9-4 drops out, the output voltage disappears, and with it the current and magnetic flux of the feedback winding. The resultant magnetic flux of the control windings acts again and the relay armature closes contacts П and Я. The armature of the actuating motor is fed with the second voltage pulse, and further the relays operate in the vibrating condition.

The D.C. component of the voltage applied to the armature of the actuating motor in unit Д15 is small, the motor rotates the sighting antenna at a low speed to reduce the magnitude of the error signal. This results in a decrease of the voltage applied from the output of the sighting and bank stabilisation unit (Д9) to the motor armature in the sighting antenna unit (Д-15М) when the homing and the sighting antennas are matched, and the motor stops. If the error signal applied to the input of unit Д9 is larger, the pulse width increases and so does the D.C. component of the voltage applied to the sighting antenna motor. The motor starts rotating the antenna at a higher speed. At a certain, still larger value of the error signal the motor rotates at full speed. This is because the magnetic flux produced by the feedback winding in the polarized relay is not capable of compensating for the magnetic flux caused by the current difference in the control windings, and the relay remains attracted all the time. As a result, relay P9-4 is permanently engaged in operation and +27 V D.C. is applied to the armature of the actuating motor.

If the homing antenna starts rotating in the opposite direction, the input of unit Д9 is furnished with an error signal in anti-phase. This increases the current in winding 3, 4 of the polarized relay and decreases accordingly the current in winding 6, 5. The polarized relay together with the power relay operate similarly and this is the condition at which contacts Я and Л of the polarized relay close, power relay P9-3 functions and the armature of the actuating motor in the sighting antenna unit is fed with the voltage of the reversed polarity.

The waveforms of the pulses furnished to the armature of the actuating motor in the vibrating condition of the unit Д -15M relay and the error pulse corresponding to them are shown in Fig.91.

The frequency of the same pulse depending upon the error signal is shown in Fig.92.

The value of the vibrating condition determines the range of proportional regulation of the system. This characteristic is dependent upon the feedback control in the relay amplifier. The feedback control is effected by potentiometer R9-17. The vibrating condition valve decreases as the voltage applied to the feedback winding of the polarized relay decreases.

The output voltage of the unit versus the current difference in the polarized relay control windings is shown in Fig.93.

The curve tilt of Fig.93 determines the transmission factor of the relay amplifier.

The output voltage of the unit versus the error signal is shown in Fig.94.

Damping is effected by capacitor C9-5 connected between the anodes of the D.C. amplifier.

In the relay amplifier pi-filters (L, C) are used on all the incoming and outgoing leads.

Contact units of relays P9-1, P9-3, P9-4 have spark-control circuits composed of capacitors C9-9, C9-10, C9-11, C9-12 and resistors R9-20, R9-21, R9-22, R9-23.

Capacitor C9-8 bridged across the output leads with capacitors C9-9 and C9-10 in the spark-control circuits reduces the noise produced by the contact units of power relays P9-3 and P9-4.

The sighting channel in unit Д9 functions only when the radar is operated in MANUAL II and AUTOTRACKING modes. This is achieved by that the input of unit Д9 is connected to the rotor of the selsyn situated in unit Д-15M only in these modes via the contacts of relay P12-5 installed in the distribution box.

Operation of bank stabilization channel

The bank stabilization channel operates in essentially the same way as the sighting channel. The only difference is that +27 V is applied to the contacts of the power relays through the pilot switches installed in the extreme positions of the bank check potentiometer in unit Д1.

Checking Unit Performance

Protective and signalling circuits

To check the performance, tuning and adjustment of the unit use is made of transformer Tp9-1 to the filament winding of which are connected potentiometers CHECK (КОНТРОЛЬ) R9-77 for the sighting channel and R9-78 for the bank stabilization channel.

From the sliders of these potentiometers an artificial error signal may be furnished to potentiometers GAIN (УСИЛЕНИЕ) of both channels with switch B9-1 in position CHECK. Rotating the sliders of potentiometers CHECK varies the artificial error signal in amplitude and phase. In the presence of the artificial error signal the unit performance is checked by pilot lamps ЛН, type CM-30.

Lamps ЛН9-1 and ЛН 9-2 are in the sighting channel and light up depending on the polarity of the voltage applied to the armature of the actuating motor and hence indicate the sense of rotation of the motor.

Lamps ЛН9-3 and ЛН9-4 serve the same purpose in the bank channel.

Lamps НЛ9-2 and НЛ9-1, type МН-5, indicate 115 V, 400 c.p.s. and 300 V D.C. The 300-V circuit is protected by a 0.25-A fuse, type ПК.

For both channels test jacks Г1 and Г2 allow monitoring of the error signal voltage at the input of the error signal amplifiers.

Jacks 1,4 allow monitoring of the input voltages of the phase detectors; jacks 2, 3, 5, 6, voltages on the control grids of the D.C. amplifiers; test jacks Г-3, Г-5 and Г-4, Г-6, the voltage between the anodes of each D.C. amplifier.; jacks 7, 8, the voltage across potentiometers CHECK (presence of an artificial error signal and filament voltage of transformer Тр9-1).

Course and pitch stabilization unit (Д-19)

The course and pitch stabilization unit is electrically and structurally identical with the bank and sighting stabilization unit. Therefore the unit functioning, i.e. conversion of the error signal voltage applied to the input of the unit into the D.C. voltage taken from the unit output is completely analogous to the functioning of unit Д-9, the functioning of the course stabilizing channel is analogous to that of the sighting channel, and functioning of the pitch stabilization channel, to that of the bank stabilization channel.

10. Tracking Unit Д-10

1. Purpose

The tracking unit is intended to control the homing antenna in all the operating modes of radar К-IIМ.

During automatic tracking error signals are separated in the unit from the selected signals coming in from the selector output of unit Д7 and converted to D.C. signals controlling the azimuth and elevation amplidynes in the automatic tracking modes.

Apart from the above, the feedback signals are amplified in the tracking unit which are then added to the main signals, and control voltage is shaped for application to the tracking motor in the autotracking and circular scanning modes. Besides, shaping of control currents is made in the unit flowing through the control winding of the azimuth amplidyne during sector scanning and manual laying.

2. Functional and basic circuits

With regard to the functions performed the unit wiring can be divided into the following circuits:

1. Circuit separating the error signal from the selected signals which includes the following elements:

(a) AGC detector employing valve Л16;

(b) resonance T-section filter RC adjusted to frequency 10 c.p.s.;

(c) error signal amplifier and phase inverter employing valve Л10-17.

2. Circuits controlling the azimuth and elevation amplidynes, each circuit including the following similar elements:

(a) phase detector with a filter in the azimuth channel employing valves Л10-1 and Л10-2, in the elevation channel, valves Л10-8 and Л10-9;

(b) shaping stage (squarer) employing valve Л10-3 in the azimuth channel and valve Л10-10 in the elevation channel;

(c) D.C. amplifier in the azimuth channel employing valves Л10-4, Л10-5, in the elevation channel, valves Л10-11 and Л10-12.

3. Circuits of the feedback amplifiers in the azimuth channel employing valve Л10-7 and in the elevation channel, valve Л10-14. Each circuit contains a damping amplifier allowing balancing of the D.C. amplifier used in the main circuit controlling the amplidynes.

4. Circuits amplifying error signals obtained from the selsyns during manual laying, each consisting of an amplifier and phase inverter:

employing valve Л10-15 in the azimuth channel and valve Л10-13 in the elevation channel.

5. Tracking circuit consists of an amplifier and a phase inverter employing valve Л10-15 (use is made of the selsyn error signal amplifier in the azimuth circuit) and a power amplifier employing valve Л10-18.

6. Sector scanning circuit which includes the following elements:

(a) phase detector employing valve Л10-21;

(b) delayed multivibrator employing valve Л10-20 and

(c) D.C. amplifier Л10-19.

The block diagram of the tracking unit is shown in Fig.95 (for convenience relays P10-1 and P10-2 in the diagram are substituted by switches). The schematic diagram of the unit is shown in Fig.108.

Separation of error signal from selected signal

During automatic tracking the circuit input is fed with selected signals from the radar channel. In the presence of an error signal these positive pulses following at frequency n_2 are modulated by frequency Ω c.p.s.

The modulation depth during automatic target tracking may vary from 0 to 10 per cent. When the target is locked on the modulation depth may reach as much as 100 per cent and even cause fading of a series of video pulses.

The input stage of the error signal circuit employing pentode 6Ж3 has a remote cutoff characteristic and performs detection, amplification and automatic gain control of the error signal.

Used as an error signal detector is the grid circuit (control grid - cathode) of valve Л10-16. When positive selected signals are furnished to the detector input, the grid circuit of valve Л10-16 in the presence of pulses will carry grid current and capacitor C10-13 will acquire charge through the internal resistance (grid-cathode) of the valve and load resistor of the cathode follower at the output of the radar of the autoselector (unit Л7) (See Fig.96).

During the resting time the capacitor is going to discharge through gridleak R10-25 and the load resistor of the cathode follower. The discharge time constant is much in excess of the charge time constant which was included in the grid-cathode section, load resistor of the cathode follower and capacitor C10-13.

The action produced by the widened grid pulses on the stage due to provision of capacitor C10-11 in the anode circuit is equivalent to the D.C. component being applied to the grid. The component is modulated by the low frequency of the video pulse envelope.

Since valve 6K3 has a remote cutoff characteristic and operation is performed with a sufficiently large amplitude of the input pulses and automatic grid bias, the automatic gain control in the stage is effected by the signal. This ensures constancy of the error signal amplitude at the input of valve Л10-16 when the modulation depth of the selected signals is constant.

Automatic gain control of error signal separation stage

As seen from Fig.96 the control grid of valve Л10-16, type 6K3, is coupled to resistor R10-25, and the valve cathode is earthed. The average value of the rectified voltage of the grid detector is the negative bias on the control grid of valve 6K3 (Л10-16).

The operating point of valve 6K3 is selected so, that the fixed bias on the control grid may be of the order of 0.5 V.

Changing the intensity of the picked-up signals changes the average value of the rectified voltage across the detector load and hence the bias on the valve grid.

On reception of weaker signals the grid bias of the valve decreases so that the gain factor of the stage increases (See Fig.99). On reception of stronger signals the grid bias of the valve increases and the stage gain factor decreases.

As a result, the signal amplitude in the anode circuit appears to be independent of the intensity of the picked-up signals.

As seen from Fig.99 the A.C. component of the anode current of valve 6K3 is found independent of the input signal level.

To make stable the AGC regulating characteristic the screen grid of valve Л10-16 is fed with a stabilized voltage of +105 V from stabilivolt СГ3С (Л10-22) (See Fig.100).

The error signal from anode of valve Л10-16 is taken to the amplifier and then to the phase inverter employing the triodes of valves Л10-17.

The anode load of the amplifying portion of the valve is resistor R10-31 and T-section image filter RC tuned to error signal frequency Ю c.p.s.

Filter RC is essentially two symmetrical T-shaped meshes connected in parallel (Fig.97).

Tuning to resonance frequency is effected by variable resistors R10-28 and R10-29.

This filter is used to apply negative voltage feedback to the grid of amplifying valve Л10-17.

At the resonance frequency the filter offers a large resistance, and the voltage fed in anti-phase from the anode to the grid of valve Л10-17 is low. At all other frequencies heavy feedback sharply reduces the voltage gain factor.

The amplified error voltage is applied to the grid of the left portion of valve Л10-17 functioning as a phase inverter.

The gain factor of the anode and cathode arms of the phase inverter is near to unity. The knob of variable resistor R10-131 serves to set the required error voltage gain factor during automatic tracking.

Circuits controlling azimuth and elevation amplidynes in autotracking

In automatic tracking when relay P10-1 is caused to operate, azimuth phase detectors Л10-1, Л10-2 and elevation phase detectors Л10-8, Л10-9 are supplied with an error voltage from the phase inverter employing the left portion of valve Л10-17.

The phase detectors shape azimuth and elevation control voltages out of the alternating error voltage and alternating reference voltages. The circuits of both channels are identical, therefore it suffices to confine ourselves to consideration of the azimuth circuit.

The phase detector uses two double triodes 6H9C. The control grids of these triodes are fed with the output voltage of the phase inverter.

The square-wave voltage is applied to the anodes of the phase detector from the anode loads of the squarer using valve Л10-3.

The reference voltage to the grids of the squarer is applied from the reference voltage generator in unit Д.

In other words, the elevation reference voltage is 90° out of phase with the azimuth reference voltage.

Fig.98 shows the simplified diagram of the phase detector and squarer.

The squarer and the phase detector function as follows:

The squarer employs valve 6H9C behaving as an overdriven amplifier.

The squarer grids are supplied with a sinusoidal voltage of the order of 80 V. In the positive alternation the sine-wave is clipped by saturation of current, and in the negative alternation by driving the valve to cut off. Thus, as a result of the squarer operation, its anodes are maintained at square voltages which after being applied to the phase detector ensure more accurate operation of the latter.

From the anodes of the squarer the square voltages are impressed on the anodes of both valves of the phase detector connected to each other. One triode is conducting, the other is cut off.

Since the cathodes of the phase detector triodes are interconnected, then irrespective of the fact which triode is open cathode loads R10-49 and R10-50 will carry direct anode current developing a voltage drop of about +76 V. D.C. component of about +75 V is fed from the phase inverter to the grids of phase detector valves. Thus the bias on the valve grids of the phase detector will be approximately -1 V.

The phase detector circuit has a cathode output, that is why its gain factor is less than unity.

When an error voltage is applied to the phase detector, its output voltage will be the result of the comparison of the error voltage phase with the phase of the reference voltages obtained from the squarer anodes.

Consider operation of the phase detector when its grids are fed with an error signal. Fig.101 presents the curves showing the voltage wareforms in various parts of the circuit when the error signal and the reference voltage are in phase.

The error voltages on grids 1 and 4 of valve Л10-2 are in phase with the respective voltages on anodes 2 and 5. The error voltages on grids 1 and 4 of valve Л10-1 are in anti-phase with the respective anode voltages. In the first alternation the right portion of valve Л10-1 and left portion of valve Л10-2 are open. The magnitude of the anode current of the valves will be determined only by the voltages on grid 4 of valve Л10-1 and grid 1 of valve Л10-2.

Since grid 1 of valve Л10-2 is fed with the positive alternation, and grid 4 of valve Л10-1 with the negative one, the current flowing through resistor R10-50 increases and the current flowing through resistor R10-49 decreases. The cathode potential of valve Л10-2 rises and that of valve Л10-1 falls. In the next alternation the left portion of valve Л10-1 and right portion of valve Л10-2 appear to be conducting. Grid 1 of valve Л10-1 is furnished with the negative alternation, and grid 4 of valve Л10-2, with the positive one. The current passing through resistor R10-50 increases again, and the current passing through resistor R10-49 decreases accordingly.

In the second alternation the voltage across the cathode sistors will change in the same way as in the first alternation. us, when the error signal and the reference voltage are in ase, the D.C. component of the cathode voltage of valve 10-2 increases, and that of valve Л10-1 decreases.

The average potential of the cathode of valve Л10-2 tained during the cycle is, in effect, the control voltage plied to the D.C. amplifier. The reversal of the error voltage ase will result in a voltage drop on the cathode of valve 10-2 and a voltage rise on the cathode of valve Л10-1, i.e. the change of polarity of the D.C. amplifier control oltage.

Operation of the phase detector when the error signal is 0° out of phase with the reference voltage is shown in Figs 03 and 104.

During the first quarter of the cycle the right portion f valve Л10-1 and left portion of valve Л10-2 are conducting. he magnitude of the valve anode current will be determined nly by the voltage on grid 4 of valve Л10-1 and 1 of valve 10-2. Since grid 1 is furnished with the positive alternation, nd grid 4 with the negative alternation, the current flowing hrough resistor R10-50 increases, and current flowing

through resistor R10-49 decreases. The cathode potential of valve Л10-2 rises, and that of valve Л10-1 falls.

At the time moment corresponding to 90° phase, the left portion of valve Л10-1 and right portion of valve Л10-2 will be momentarily initiated into conduction. In the consequence of is [illegible] grid 1 of valve Л10-1 and grid 4 of valve Л10-2 will start controlling the anode current of the valves. Since the voltage on grid 1 is a maximum and that on grid 4 is a minimum, the cathode potential of valve Л10-1 will rise, and the cathode potential of valve Л10-2 will abruptly fall to minimum. The left portion of valve Л10-1 and the right portion of valve Л10-2 will be made to conduct in the interval between the phase angles from 90° to 270° as a result of which grids 1 and 4 will control the anode current of the valve.

The cathode potentials change with the grid potentials.

At 270° the cathode potential of valve Л10-2 is a maximum and that of valve Л10-1 is a minimum. The change of the anode voltage at 270° will result in that the right portion of valve Л10-1 and left portion of valve Л10-2 are open, and the anode currents are controlled by grid 4 of valve Л10-1 and grid 1 of valve Л10-2. Since at this moment the potential of grid 4 is a maximum, and the potential of grid 1 is a minimum, the cathode potential of valve Л10-1 rises sharply and that of valve Л10-2 falls to a minimum.

From this time on to the end of the period the cathode potential of valve Л10-1 will change with the change of potential of grid 4, and the cathode potential of valve Л10-2 with the change of potential of grid 1.

The cathode voltage curve (See Fig.104) being symmetrical in relation to the initial level, the average value of both cathode potentials remains the same as it was with no error voltage applied to the grids.

Thus, when the error voltage is shifted in phase by ±90° with respect to the reference voltage, the control voltage is zero.

From the above two examples it follows that if the azimuth phase detector is furnished with an error signal caused by the target displacement in azimuth it will be in phase with the azimuth reference voltage and the azimuth control voltage is obtainable from the output. This error signal creates no control voltage in the elevation phase detector, since the elevation reference voltage is quadrature-shifted with the azimuth reference voltage. Since during automatic tracking the grids of the squarers in the azimuth and elevation channels are fed with voltages shifted in phase by 90° with each other at frequency Ω, the output voltages of the detectors are found proportional to cos φ for the elevation phase detector and to sin φ for the azimuth phase detector, where φ is the angle between the axis of the equisignal zone and target direction.

The phase detector output voltage is fed to the control grids of the balanced amplifier through filter R10-51, C10-24, and R10-52, C10-25.

The output control voltages of the azimuth and elevation phase detectors may be set equal by means of resistors R10-49, R10-50, R10-73 and R10-74, which allows to set the equal rate of following up in both directions.

The D.C. balanced amplifiers in the azimuth and elevation channels employ tetrodes 6П6С. The circuits of the channels are identical, therefore functioning of the azimuth D.C. amplifier is only considered.

The anode loads of the D.C. amplifier valves are the control windings of the amplidynes.

The cathodes of the D.C. amplifier valves are coupled together and a voltage drop of about +81 V is developed across resistors R10-56 and R10-57.

The magnitude of this voltage drop is independent of unbalance since the D.C. amplifier is a balanced unit (the increase of voltage on one grid is inversely proportional to the voltage drop on the other, the resultant current through the cathode load remains invariable).

In the absence of an error signal the control grids of the D.C. amplifier are supplied with approx. +76 V. Thus the initial bias of the D.C. amplifier valves will be about -5 V. The variable resistor in series with the fixed one serves for adjusting this operating voltage.

Balance of the D.C. amplifier is achieved by the adjustment of screen voltages carried out with the damping amplifier and potentiometers located in the control panel.

When the error voltage is zero or 90° out of phase with the reference voltage, the anode currents of the D.C.

amplifier are equal and oppose each other. In this instance, the output voltage of the amplidyne is zero.

The unbalance voltage which is the result of the phase detector functioning causes a proportional unbalance of currents in the control windings of the amplidyne, the signs of unbalance of these current changing with the reversal of polarity in the phase detector output voltage. This, in turn, causes appearance of the corresponding voltage turning off the homing antenna.

Antihunt circuits and balancing in azimuth and elevation channels

To ensure stability and the required dynamic characteristics of the system incorporating tracking unit Д10 and homing antenna Д1, it is provided with antihunt circuits (flexible feedback) by means of which regulated voltages are injected. The simplified feedback and balance circuit diagram is shown in Fig.105.

As the feedback circuits in both channels are identical, only the azimuth channel is under consideration.

The feedback voltage is applied to the grid of the left portion of the feedback damping amplifier valve Л10-7 from the armature terminals of the azimuth actuating motors via special circuits RC in unit Д-13М, the grid of the right portion is fed with balancing voltage of +27 V from the divider in the control panel.

Load resistors R10-58 and R10-59 in the anode circuits of the damping amplifier are at the same time balance resistors of the D.C. amplifier screen grids.

In the common cathode circuit of valve Л10-7 a voltage drop of about +32 V is developed across resistor R10-66. Thus, the grid bias on both grids will be approximately -5 V. This resistor in the cathode ensures a balanced input of the amplifier with the unbalanced input.

When the anode currents of the damping amplifier are equal, the potentials of the D.C. amplifier screen grids will be equal and will not cause unbalance of the anode currents passing the control windings of the amplidyne.

Potential to the grid of the right-hand triode of the damping amplifier is applied from variable resistor R11-51. By changing its value it is possible to set a fine balance of the D.C. amplifier anode currents, thereby compensating for the spread in characteristics of the valves and circuit elements.

When a positive signal appears on the grid of the left triode of the damping amplifier, the anode current increases, which in turn, causes a voltage drop on the screen grid of the D.C. amplifier.

But even the screen grid potential of the D.C. amplifier second valve does not remain constant.

Indeed, the bias rise on the grid of the right triode applied from the cathode circuit causes the anode current of the right triode to decrease thereby increasing the screen grid potential of the D.C. amplifier.

As a result of such variation of the screen potentials a symmetrical unbalance of the D.C. amplifier anode currents is obtained.

This unbalance is furnished reversed to the D.C. amplifier to compensate for the unbalance caused by the error voltage. This damps the diverging oscillations of the entire system.

Changing to circular scanning is effected by unbalancing. The unbalancing voltage is supplied from a voltage divider located in the control panel. The degree of unbalance determines the rate of scanning.

Variation of the degree of unbalance during circular scanning is carried out by means of potentiometer R11-50 RATE OF CIRCULAR SCANNING (СКОР.КРУГ.ПОИСКА) located in the control panel.